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LUNAR FACSIMILE CAPSULE PROGRAM

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SECTION 1

INTRODUCTION

Aeronutronic Division of Ford Motor Company, under JPL Contract, is developing major subassemblies of the landing sphere assembly for the Lunar Facsimile Capsule (LFC). The LFC is basically the Ranger Seismometer Capsule with a high-resolution facsimile device replacing the seismometer experiment. The LFC transmits data to reproduce on earth a complete 360-degree panoramic view of the lunar terrain surrounding the landed capsule. The viewing system scans from 10 degrees above the horizon to within 4 feet of the capsule, is in focus from about 4 feet to infinity, and has an angular resolution approaching 0.1 degree. The facsimile picture includes an accurate profile of the entire lunar horizon, as well as resolutions down to 0.1 inch in the near field.

The LFC development is planned in three phases. Effort is currently authorized on Phase I, covering an 8-month period, with the primary objective of demonstrating the ability of the prototype LFC to a simulated lunar impact. The complete viewing system, with its associated azimuth drive and extension mechanisms installed in a prototype structure, will be subjected to a simulated lunar impact, followed by functional testing. Following further development to correct any deficiencies in the first prototype test, a second prototype viewing subsystem will be impacted and subjected to functional testing. An objective of the functional tests will be to scan and record at least one 360-degree facsimile picture, followed by reproduction of a photo facsimile with a developmental reproduction system.

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Phase I also includes effort on a breadboard porting mechanism and a prototype solid-state transmitter. The porting mechanism effort will investigate dynamic porting characteristics to produce vital design data with special attention to reaction impulse and tipoff effects which might overturn the landing sphere assembly. The transmitter shall be developed to meet the power and efficiency objectives of the LFC design and shall be packaged in an assembly compatible with the payload sphere configuration.

The Phase I effort is not dependent upon development efforts of any outside subcontractor.

SECTION 2

SUMMARY OF PROGRAM STATUS

Effort on all tasks is progressing essentially as planned. Final Design Reviews have been held, and drawings of the first prototype have been released.

Developmental and breadboard models of most subassemblies have been fabricated and functional tests of these breadboards initiated. The completion of fabrication of parts for prototype subassemblies is taking slightly longer than expected; however, the program schedule is not considered to be in serious jeopardy at this time.

Table I presents a status summary of each task.

TABLE I
PROGRAM STATUS

<u>Task</u>	<u>Status</u>
1. Preliminary Design and Quality Assurance	Assembly Design Review. Conducted First Prototype Assembly Drawings Released Reliability Analysis and Failure Mode Study Published Redundancy Study Completed Dummy Subassemblies Fabricated Prototype Payload Size Frozen Prototype Weight and Volume Allocations Formalized
2. Prototype Top Tube Development	Design Review Conducted Design of Preamplifiers Completed First Prototype Design Released Fabrication of Parts for First Prototype in Progress Design Specifications Revised Delivery of Parts Delayed Motor Does Not Meet Specifications Vacuum Tests Complete Preprototype Impact Test Complete New Sensors Received and Measured Preamplifier Packaging Nearing Completion
3. Prototype Azimuth Drive and Extension Mechanism Development	Design Review Conducted First Prototype Design Released Azimuth Drive Gear Heads and Motors Procured Extension Mechanism Developmental Model Assembled and Tests in Progress First Prototype Parts Nearly Complete Design Specifications Revised Prototype Drawings Released Motors Do Not Meet Specifications

<u>Task</u>	<u>Status</u>
4. Test Structure Development	Design Review Conducted Fabrication of Breadboard Model Initiated First Prototype Design Released Design Specifications Revised
5. Breadboard Motor Drive and Signal Electronics Development	Circuit Design Released Fabrication of First Breadboard Models Completed Informal Design Review Conducted Motor Drive Electronics being Changed to Operate Motors New Concept in Signal Electronics Initiated
6. Breadboard Ground Reproducibility Development	Reconditioning of Mechanical, Elec- tronic, and Optical Components Completed Film Evaluation Completed Film Processing Evaluation in Progress
7. Prototype Assembly and Testing	Clean Assembly Area Nearly Complete Fabrication of Impact Limiters for Prototype Tests Started Flotation Fluid Shells Available Prototype Parts Being Accumulated Impact Acceleration Instrumentation Improved Preliminary Draft of Prototype Test Plan Prepared Sled Impact Limiter Qualified for Higher G Levels Test Sled Improved for Higher G Levels Assembly Procedures and Assembly Log Books Prepared

<u>Task</u>	<u>Status</u>
8. Breadboard Porting Mechanism Development	Second Phase Tests Completed Evaluation of Test Results Completed Final Report in Preparation .
9. Prototype Transmitter Development	Design Review Conducted Redesign and Layout Nearly Complete Preprototype Test Housings Fabricated Design Specifications Released.
10. Systems Integration	Signal-to-Noise Analysis Complete Optical Parameters Formalized Launch and Trajectory Constraints Specified Functional Test Targets and Lighting Being Specified

SECTION 3

SYSTEM CONSIDERATIONS

3.1 PAYLOAD PRELIMINARY DESIGN

Phase I payload preliminary design effort includes the design of a configuration layout and the specification of interfaces for those subassemblies under prototype development. The effort also includes review, upgrading, and recording of subassembly physical requirements of those subsystems under preprototype development. During this reporting period, major emphasis has been placed upon the areas described below.

A Design Review of the LFC Flight Assembly (Preliminary Design) has been held, and no significant changes were recommended. The payload design concept retains the capability of nondestructive replacement and/or repair of major subassemblies including interchangeability of components and subassemblies.

The payload power supply has been revised to 11.7 pounds and a minimum of 2.9 pounds of thermal control fluid has been allocated as a result of decreasing the steady state power requirement from 45 to 38 watts. This will provide 15.4 hours of operation on the lunar surface and approximately 700 degrees of picture viewing angle. In addition, a diode protection circuit has been selected to provide a redundancy feature in the LFC Power Supply.

A trip was made to Electric Storage Battery Company, Raleigh, North Carolina, to discuss the LFC battery requirements, obtain revised estimates of performance and present several alternate configurations for consideration. ESB anticipates that the storage capacity of the

battery will be about 20 percent higher than the preliminary design indicated and essentially confirmed that the selected parameters were entirely adequate, and in several cases conservative. The expected operational level of the battery is a maximum of 30 volts and a minimum of 26 volts, which is acceptable for the electronic subassemblies. The RF output of the transmitter will vary between 2.5 and 3.0 watts over this voltage range.

A survey has been made to determine in what areas redundancy techniques could be employed in the LFC payload sphere. A summary of these areas includes the following:

- (1) Redundant battery utilizing diode protection circuit.
- (2) Redundant elements in the extension mechanism to aid in erection and locking.
- (3) Redundant motor and gear box in the azimuth drive utilizing one-way couplings on the worm shaft.
- (4) Redundant antennas or passive cavity antenna.
- (5) Parallel 'g' switches to activate the sequence timer.
- (6) Redundant squibs for porting, caging, and switching.
- (7) Two separate water tanks and valves for temperature control.
- (8) Redundant circuitry and redundant mode operation in the motor drive electronics and signal and synchronization electronics.
- (9) Partial redundant circuitry by parallel operation of the components as well as consideration of completely redundant transmitter.
- (10) Redundant components in the top tube including scanning mechanism, sensor and preamps.

Some of these elements are presently included in the first prototype subassemblies; for example, component failure such as switches could occur and still provide a satisfactory but degraded picture. Others would be more seriously considered during Phase II while the remaining may not prove practicable at all.

Weight allocations have been revised to be compatible with prototype subassemblies as shown in Table II. Most of the first prototype subassemblies have been weighed. The significant changes include increase in payload structure weight to now include all hardware and fasteners and a decrease in the payload power supply because of lower power consumption. In addition, the weight allocation for the azimuth tube has been transferred from the extension mechanism. The first prototype test sphere is expected to weigh 43.9 pounds not including a growth allowance of 0.1 pound.

Some difficulty had been experienced in the fabrication of extension tubes because of thin walls and consideration was given to increasing the wall thickness to ease manufacture. More recently, vendors have been producing acceptable parts, and therefore no change in the design is anticipated at this time.

Microminiature connectors have been procured and assembled in a test fixture for impact feasibility tests. The connectors will be impacted in a sled at 3000 g. Electrical continuity will be monitored during impact. Momentary disconnection will not constitute a failure, although permanent impact damage will be considered a serious malfunction.

Fabrication of all dummy subassemblies required for developmental and first prototype tests is now complete. A dummy transmitter housing closely simulating the prototype transmitter under development is to be included.

3.2 SYSTEM STUDIES

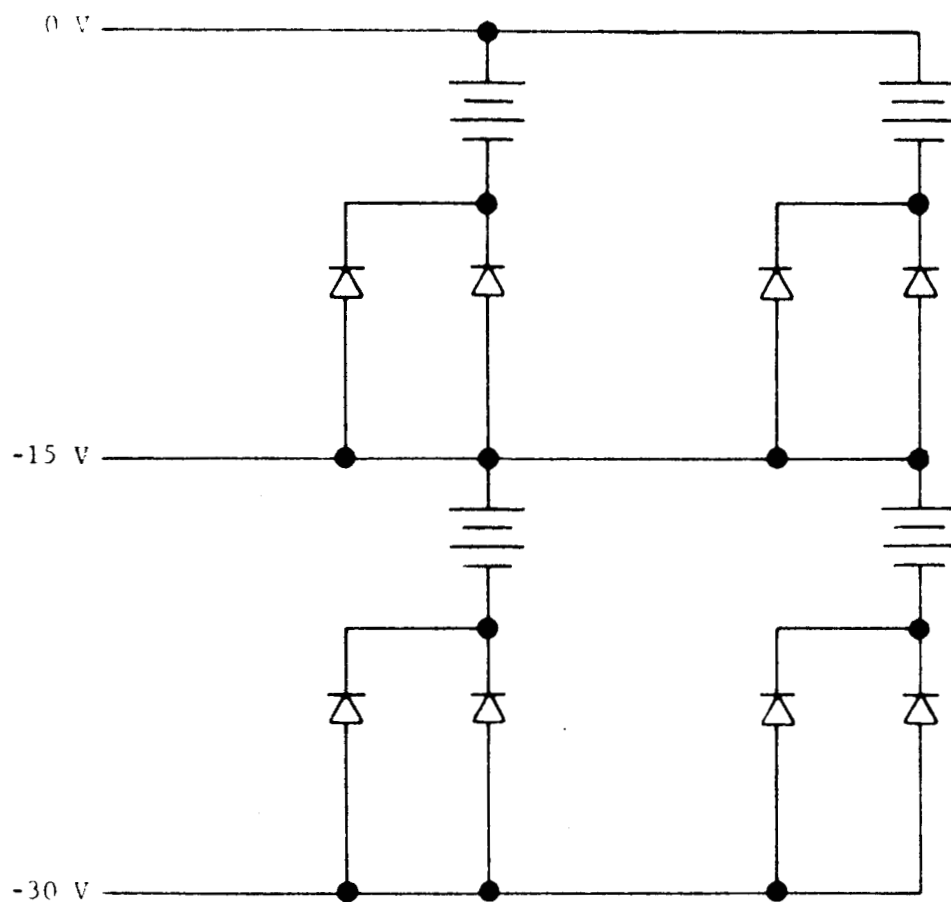
LFC power consumption is currently estimated at 35.85 watts. In order to provide a more reliable battery, it has been decided that four identical 15 volt modules will be used and the modules will be protected by dual diode separation as shown in Figure 1. This circuit provides parallel diode protection of each cell and allows any one cell (or module) to fail or any two cells (or modules) to fail providing they are not at the same voltage level. Estimated power consumption of

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TABLE II
LUNAR FACSIMILE CAPSULE WEIGHT SUMMARY

	<u>Weight, lb</u>	
	<u>Previous*</u>	<u>Present</u>
	<u>Estimate</u>	<u>Estimate</u>
Top tube assembly	1.2	1.2
Azimuth drive assembly	0.45	0.60
Extension mechanism	0.40	0.30
Porting mechanism	5.0	5.0
Cage/uncage system	1.5	1.5
Payload sequencing unit	0.7	0.7
Transmitter and VCO	2.8	2.8
Payload power supply	13.45	12.75
Signal and synchronization electronics	0.85	0.85
Motor drive electronics	0.7	0.70
Thermal control system	4.0	4.0
Payload structure	11.5	11.95
Ballast	0.5	0.5
Wiring	1.0	1.0
Growth allowance	0	0.1
Instrument payload	44.05	44.0
Flotation fluid	2.33	2.33
Flotation fluid shell	4.86	4.86
Impact limiter	29.86	29.86
Covers	5.8	5.8
Attachments	1.6	1.6
Landing sphere	88.5	88.5
Power and sequencing assembly	1.22	1.22
Vibration damper assembly	0.98	0.98
Upper clamp assembly	0.23	0.23
Attachments	0.44	0.44
Retromotor payload	91.4	91.4
Retromotor	214.74	214.74
Spin motor and attachments	7.04	7.04
Lower clamp assembly	1.14	1.14
Retromotor/landing sphere		
support structure and attachments	3.50	3.50
Thermal radiation shield assembly	4.83	4.83
Altimeter and support assembly	10.38	10.38
Bus-mounted capsule	333.0	333.0

*Expected weight as of 22 Feb. 1963
as reported in Bi-Monthly Technical Progress Report No. 2



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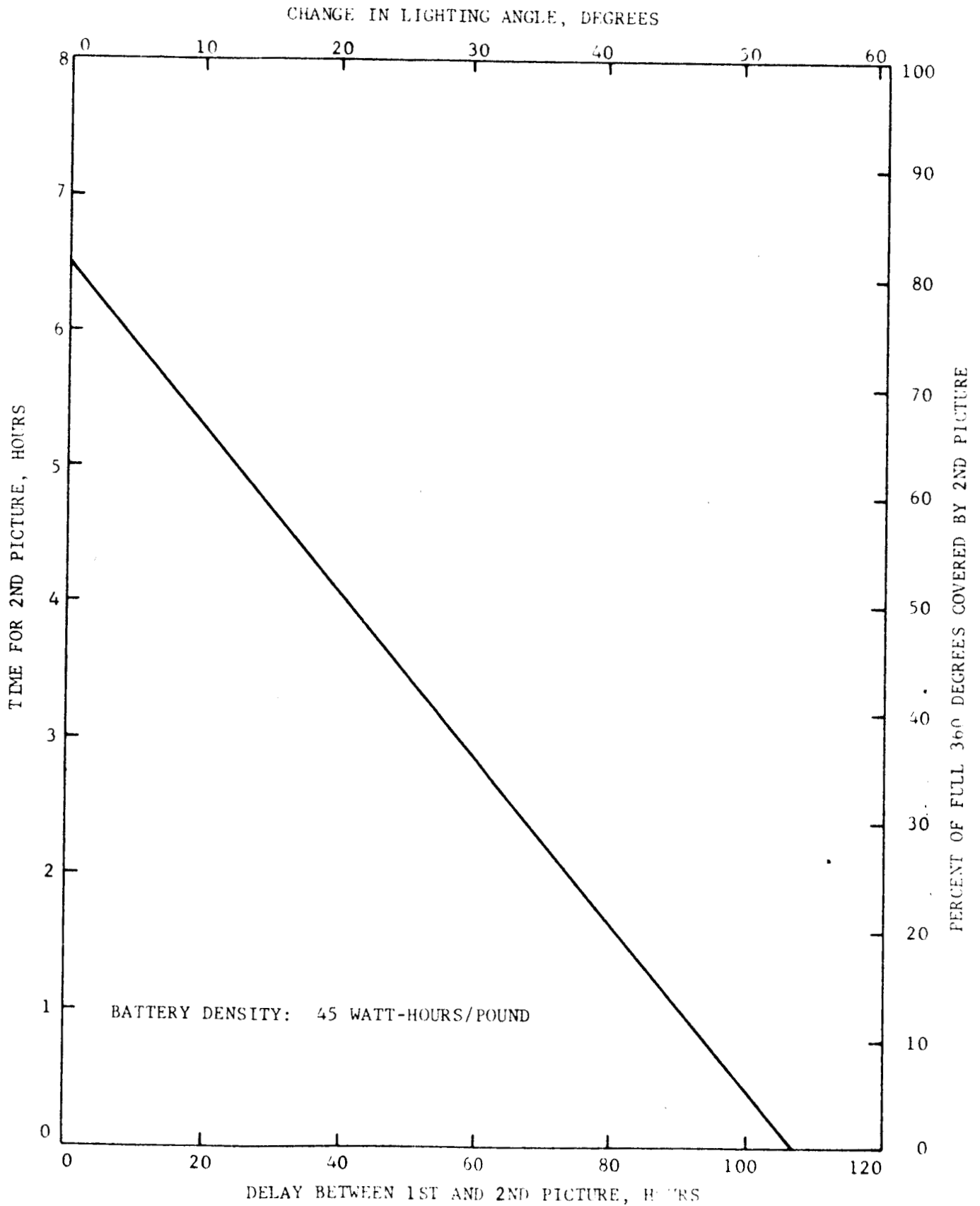
FIGURE 1. PAYLOAD POWER SUPPLY
AND DIODE PROTECTION CIRCUIT

the diodes is 2.15 watts; thus the overall power required is 38 watts. Within the current 14.6 pounds weight allowance for battery and thermal control fluid, it is estimated that 15.4 hours of operation (696 degrees of picture) is available with a 50 watt-hour/pound battery. However, assuming a density of 45 watt-hour/pound, then this coupled with the water required for heat dissipation leaves 6.7 pounds of water and battery for additional coverage after one 360 degree picture is obtained in the first 8 hours of operation. Figure 2 shows the available coverage left for a delayed second picture.

Figure 3 is a composite chart indicating the dependence between optical parameters. Selection of any four independent parameters is necessary and sufficient to establish values for the remaining four parameters. The optics parameters for the LFC prototypes have now been firmly established. Data of interest are shown in Table III. The operating parameters given above are shown in Figure 3 yielding a depth of focus of 3 millimeters and a focal ratio of about $f/24$. The lens aperture is greater by more than a factor of 4 than that required by the Rayleigh criterion to be assured that optical refraction will not present serious degradation. The angular resolution referred to in Figure 3 is that which occurs at the hyperfocal distance. The resolution varies, however, throughout the depth of field but never gets worse than twice that at the hyperfocal distance as shown in Figure 4.

The lens will be a coated achromatic contact doublet of ordinary crown and flint corrected for wave lengths 0.55 and 0.95 microns. The viewing window will be coated fused quartz. Two types of mirrors are currently being considered and tested. The mirrors to be used will be either (1) aluminum deposited on fused quartz, or (2) aluminum deposited on a polished nickel surface. System measurements of transmissability have not yet been made, however, it is estimated to be about 0.75.

Some studies have been completed and others are continuing in support of the system functional demonstration tests. Various methods of approximating solar radiation have been reviewed. Some filtered sources, particularly xenon-mercury combinations, have been found to possess good spectral approximations. However, mechanization with the vacuum chamber and to the intensity levels required would be exorbitantly expensive. Moreover, laboratory tests of tungsten sources compared to direct viewing of the moon have shown the performance may readily be compared between the two. It has therefore been decided that the tungsten system presently available within the vacuum chamber will be utilized.



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FIGURE 2. SECOND PICTURE COVERAGE AFTER A FIXED DELAY.



FIGURE 3. TRADE-OFF CHART OF TOP TUBE OPTICAL PARAMETERS

TABLE III

PROTOTYPE OPTICAL PARAMETERS

Lens Aperture Diameter	0.349 cm
Hyperfocal Distance	200.0 cm
Pinhole Diameter	0.015 cm
Distance Lens to Pinhole	8.60 cm
Focal Length	8.25 cm

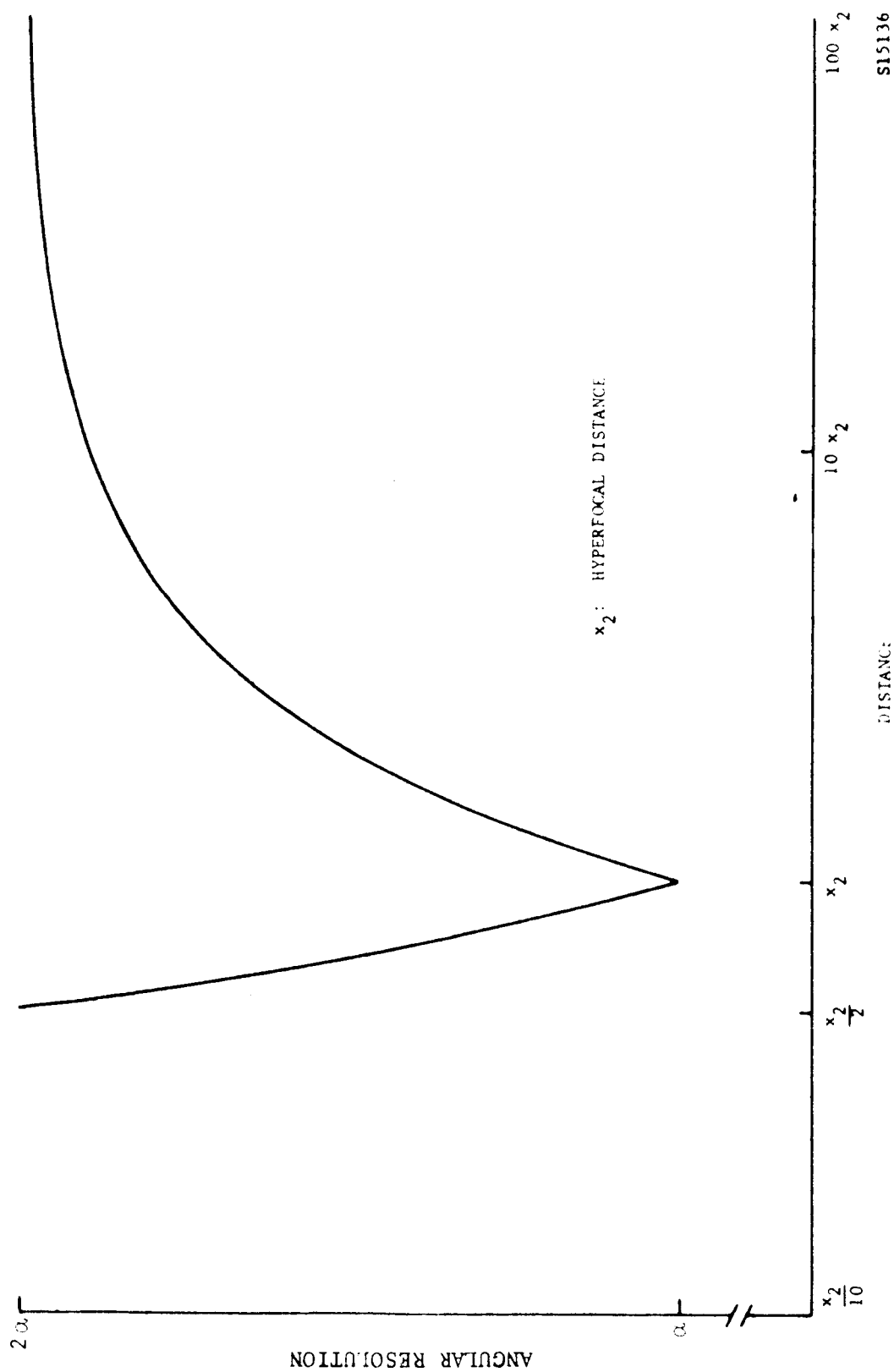


FIGURE 4. DEGRADATION OF ANGULAR RESOLUTION

Targets are presently being designed to provide systems test data on resolution, linearity and dynamic range. Target illumination will range from 25 to 2500 foot-Lamberts even though, as discussed below, it is expected that some of the breadboard electronic components may limit system range capability below 100:1.

The general system test configuration will be made up of the aforementioned "lunar test scene", the LFC prototype top tube assembly, breadboard versions of associated motor drive and signal electronics, power supply, a magnetic tape recorder and the breadboard LFC ground reproducer. Composite data and 400 cycle per second reference signal will be processed in real time for reproduction on the ground reproducer and also recorded on magnetic tape for subsequent playback and reproduction.

The prototype top tube, which includes the sensor/preamp electronics is designed for the full 40 db dynamic range and frequency response requirements. Similarly, the breadboard sync and signal electronics will accommodate the input signal range requirements. In particular, the standard IRIG (5.4 Kc) subcarrier frequency channel which accepts the data signal for subsequent FM transmission over the data link is estimated to possess a 40 db dynamic range under test conditions. This is based upon signal instability due to long-term drift and temperature and power supply variations which contribute uncertainties on the order of 1 percent of signal range. It is presently contemplated that a CEC GR-2800 tape recorder/reproducer will be employed to record and subsequently playback test data. The dynamic range capability of the recorder coupled with normal FM improvement obtained in FM discrimination and added low-pass filtering is currently under investigation. Some compromise in Phase I system test dynamic range requirements are contemplated in certain of the associated test hardware; for example the tape recorder. However, a more exact estimate of actual overall dynamic range will be derived following a review of various subsystems and associated equipment test data when it is obtained prior to system testing.

Final evaluation of the LSX-511 sensor and field effect transistor preamplifier have been completed. The peak detectivity is 5.4×10^{11} cm-cps^{1/2}/watt at a wave length of 0.9 microns and its noise equivalent power (NEP) is 10^{-12} watt. The signal-to-noise ratio in a 130 cps bandwidth which can be expected at the output of the preamplifier is shown in Figure 5. This performance is based upon accumulation of all negative tolerances. Even so, it is better by more than a factor of 3 than that previously reported. A recent test with this sensor under full moon elimination yielded results which were within 10 percent of its predicted performance.

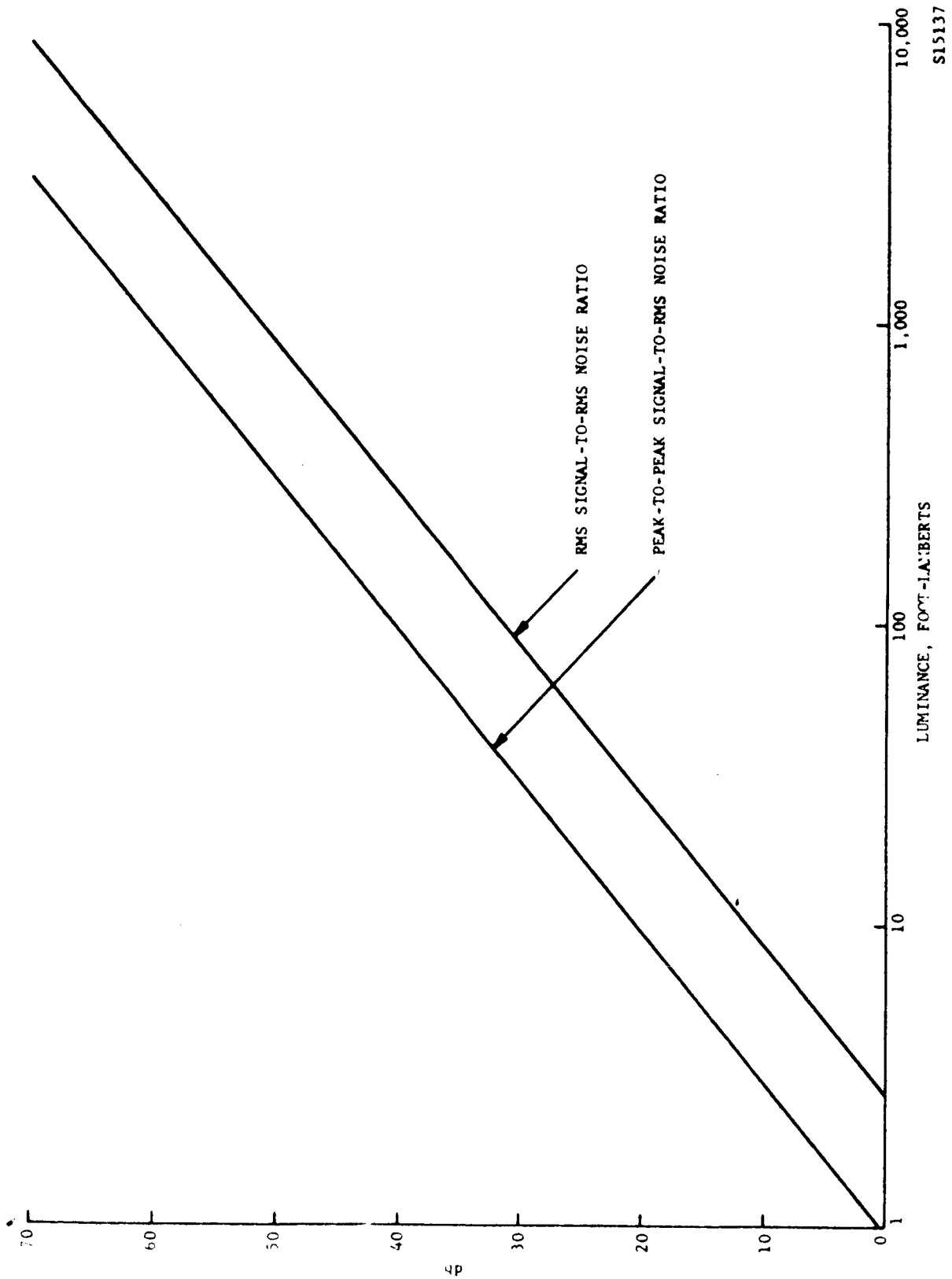


FIGURE 5. SIGNAL-TO-NOISE RATIO AS A FUNCTION OF LUNAR SURFACE LUMINANCE AT OUTPUT OF LSX-511 SENSOR/PREAMPLIFIER

If all of the negative communication tolerances are additive, then a power ratio of signal-to-receiver noise of 5000:1 (37 db) may be expected at the output of the DSIF phase lock discriminator. The low light (25 foot-Lamberts) signal-to-preamp noise power ratio of 80:1 (19 db) which is present in the capsule would be degraded to 78.6:1 which is less by a fraction of a db.

Further improvement in signal-to-noise ratio may be gained by variation in the optical parameters. If the resolution is relaxed, an improvement in signal-to-noise ratio proportional to the fifth power of the instantaneous field of view may be realized.

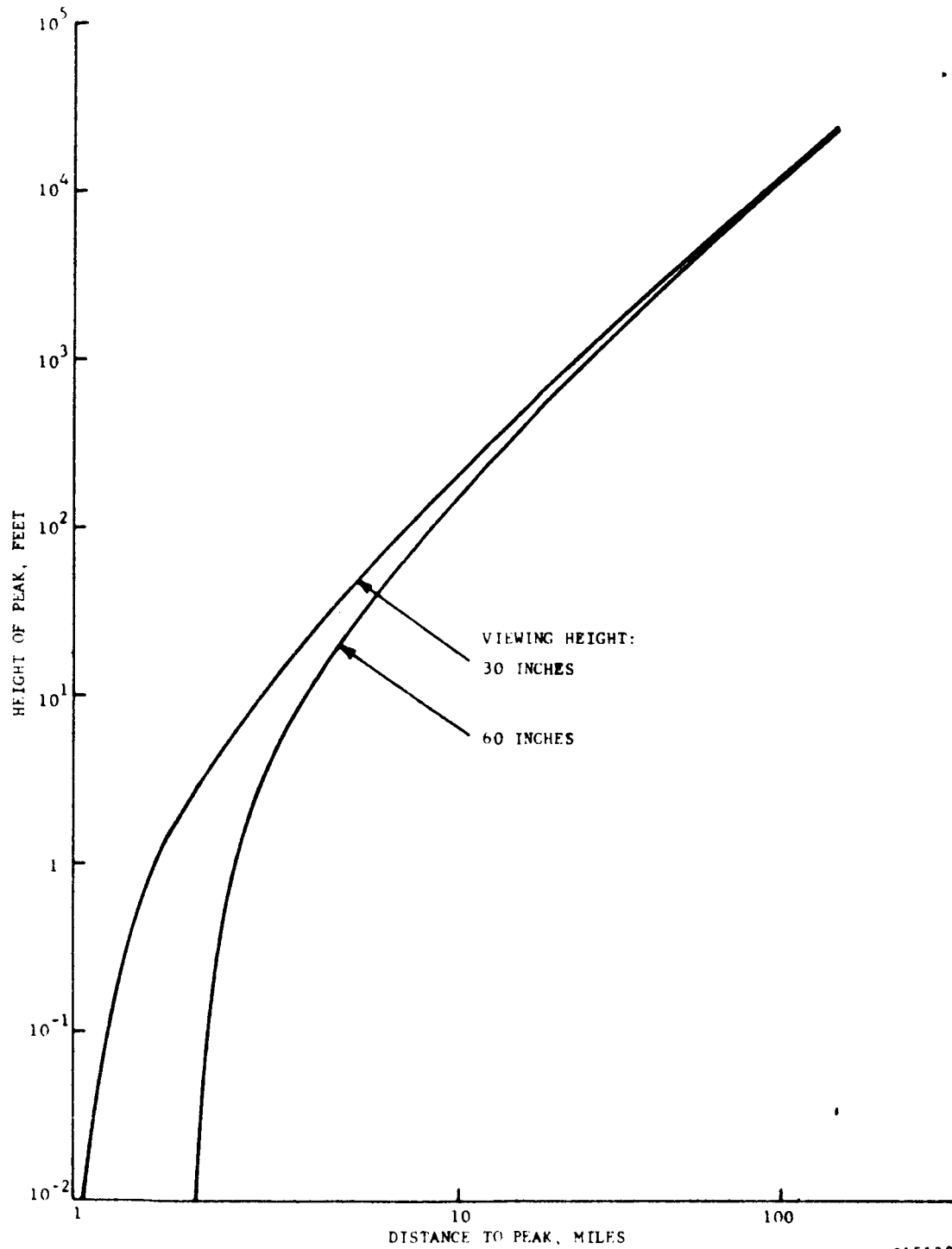
In figure 5, an rms signal-to-rms noise ratio of 3.0 occurs at 8 foot-Lamberts. This may be thought of as one "grey" level since the electrical signal corresponds to the 3-sigma value of the noise. At this low light level, one expects to recover the signal 99 percent of the time: the probability of the noise exceeding its 3-sigma value being 0.01. This being the case, the number of such signal levels between 8 and 2500 foot-Lamberts are more than 300.

On the other hand, for photographic reproduction and subjective viewing, the number of shades of grey S has been defined as the ratio $B_1/B_2 = 2^{S/2}$. Where B_1 and B_2 are the upper and lower luminance extremes. A total number of grey levels for the LFC system greater than 13 is to be realized from 25 to 2500 foot-Lamberts.

The maximum distance at which protruding objects on the lunar surface can be observed by the LFC is shown in Figure 6 for viewing heights of 30 inches and 60 inches. The curves are asymptotic, and indicate that the distances to the horizon are 1.01 and 2.02 miles respectively.

Three constraints which are most likely to have direct bearing on subsequent selection of launch date, launch window, and earth-moon trajectory have been specified.

- (1) The angle subtended by the earth-moon line and the lunar local vertical should be no greater than 40 degrees based upon telecommunication considerations.
- (2) The angle subtended by the sun-moon line and the lunar local vertical should be no less than 50 nor more than 70 degrees based



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FIGURE 6. MAXIMUM DISTANCE AT WHICH A PROTUBERANCE
CAN BE SEEN ON THE LUNAR SURFACE

upon good shadow definition and prevention of direct solar observation, respectively.

- (3) The impact angle should be no greater than 10 degrees based upon the limitations of previous studies of the impact limiter and landing system.

3.3 SYSTEM ASSEMBLY

Impact limiter design and test levels for the prototype tests have been revised. To conform with LFC Phase I program requirements, a single payload of 10-3/4 inches in diameter will be utilized. All flotation fluid shells and limiters will also be the same size throughout Phase I to allow for timely procurement of these components. Deviations in size may be accommodated in Phase II.

During the early portion of Phase I, a 24.6 inch diameter impact limiter was designed using the landing sphere weight of 86.9 pounds. This contained a 43.1 pound 10-3/4 inch diameter instrument sphere. Experience from Ranger Seismometer Capsule Program has indicated that a 10 percent energy absorption design margin is desirable. This reduces the maximum velocity capability to 200 feet per second. This is not sufficient for nominal 200 feet per second HYGE tests, since past experience has indicated a variation of 10 percent in the control of test velocity. Consequently, the Phase I prototype test impact limiter diameter has been increased to 25.75 inches. The outer radius of the upper hemisphere has been offset 1.75 inch to remove an additional 3.5 pounds of balsa wood for the tests. This provides a 215 feet per second normal impact velocity capability. With a 10 percent energy absorption design margin, the predicted impact velocity for the test sphere weighing approximately 88 pounds is 200 feet per second.

Caging of the prototype sphere during the acceleration phase of the HYGE test in order to obtain the proper orientation to the path of travel at impact will be accomplished by bonding rubber pads to both payload and inner shell to provide the torsional restraint required.

The balsa wood blocks for the impact limiter have been received, segments cut and are now ready for the first bonding operation. The flotation fluid shell hemispheres have been received and are ready for assembly. Tooling and material required for fabrication of the rubber cover has been ordered.

Detailed assembly procedures, assembly drawings, records, a flow chart, a parts list and a weight record have been prepared and will be used in the developmental structure assembly in preliminary form. This procedure will allow ample time for their revision for the first prototype and subsequent landing spheres, if required.

No final assembly work has yet been accomplished on the No. 1 prototype payload. Detail parts and materials are now being accumulated for this assembly, and approximately 50 percent of the required parts are in the assembly bond cabinet. The majority of the remaining parts are major subassemblies.

Space at the Newport Beach Facility has been converted to a Clean Room for assembly of the LFC payload. The 20 x 45 foot room has been put on a special air conditioning system. Hallway windows and an air lock vestibule have been installed. A limited number of special benches and equipment will be installed in the room. Dacron clean room uniforms have been ordered, and a Class II Clean Room Procedure is to be observed at all times. The room should be ready for use in time for the No. 1 Prototype Assembly.

3.4 SYSTEM TESTING

A preliminary draft of the prototype No. 1 test plan has been completed and is awaiting final release. The prototype assembly will undergo the following major environmental tests:

- (1) Launch Vibration Tests
- (2) HYGE Sphere Impact
- (3) Vacuum Functional Test
- (4) HYGE Sled Impact

During the vacuum functional test, photographic data will be obtained on a tape recorder. The tape will be played into the ground reproducer and a picture will be produced. The data will be examined for resolution, dynamic range and linearity. The ground reproducer may also be used in parallel with the tape recorder during the functional test to obtain a real time picture.

Vertical motion characteristics of the top tube scanning mirrors will be determined with an Optron Model 701 tracker. Attempts

were previously made using a film potentiometer coupled to the cam follower pivot as a transducer to obtain dynamic shaft angle measurements with a precision of 0.005 degrees in a total deflection of 25 degrees. An analog computer was used to generate a voltage ramp equivalent to ideal cam follower motion. The difference between the transducer output and the ideal ramp was displayed on an oscilloscope as position error. The error signal was analyzed as being predominately noise generated by the transducer and was much greater than the magnitude of mirror motion error.

The Optron tracker will detect errors in excess of 0.05 degrees in a full 25 degree sweep. The smallest discernible error can be reduced to a sufficiently small value by inspecting the sweep in segments rather than the full sweep; i.e., if 25 degrees of mirror motion were equal to full scale out of the tracker then the tracker could resolve mirror motion errors as small as 0.005 degrees.

Target and lighting requirements for the LFC prototype functional tests are being defined. Lighting for the LFC functional tests will be the variable-intensity tungsten system already available in the Aeronutronic Vacuum Chamber. The lamps will be operated sequentially in 4 banks for 16 hours (equivalent to 720 degrees of picture). Targets to determine the system dynamic range, angular resolution, scan linearity and the grey scale capability of the photographic process are being designed. Geometry, number, location, orientation, painting and luminance of the targets has been specified as well as a miscellaneous display box which will contain pebbles and rocks.

Capability to produce higher reaction loads and thereby increase deceleration levels has been achieved by incorporation of a new limiter designated Mark VIIIB. The Mark VIIIB limiter consists of a Mark VIII balsa wood limiter stiffened with four one-inch diameter nylon rods to give increased load stroke characteristics. The estimated "G" level increase resulting from this modification is 700 "G". To withstand the higher loadings, the HYGE sled has been reinforced with bonded shear skins. Figure 7 is a photograph of the modified sled contacting the Mark VIIIB limiter.

Instrumentation for the sled tests consists of 2225 and/or 2215 Endevco accelerometers mounted on the sled, a 3/4 million pound load cell mounted under the impact limiter and photo cells. Measurements obtained from the various instrumentation during two tests are shown in Table IV. During both of these tests the 2215 accelerometers

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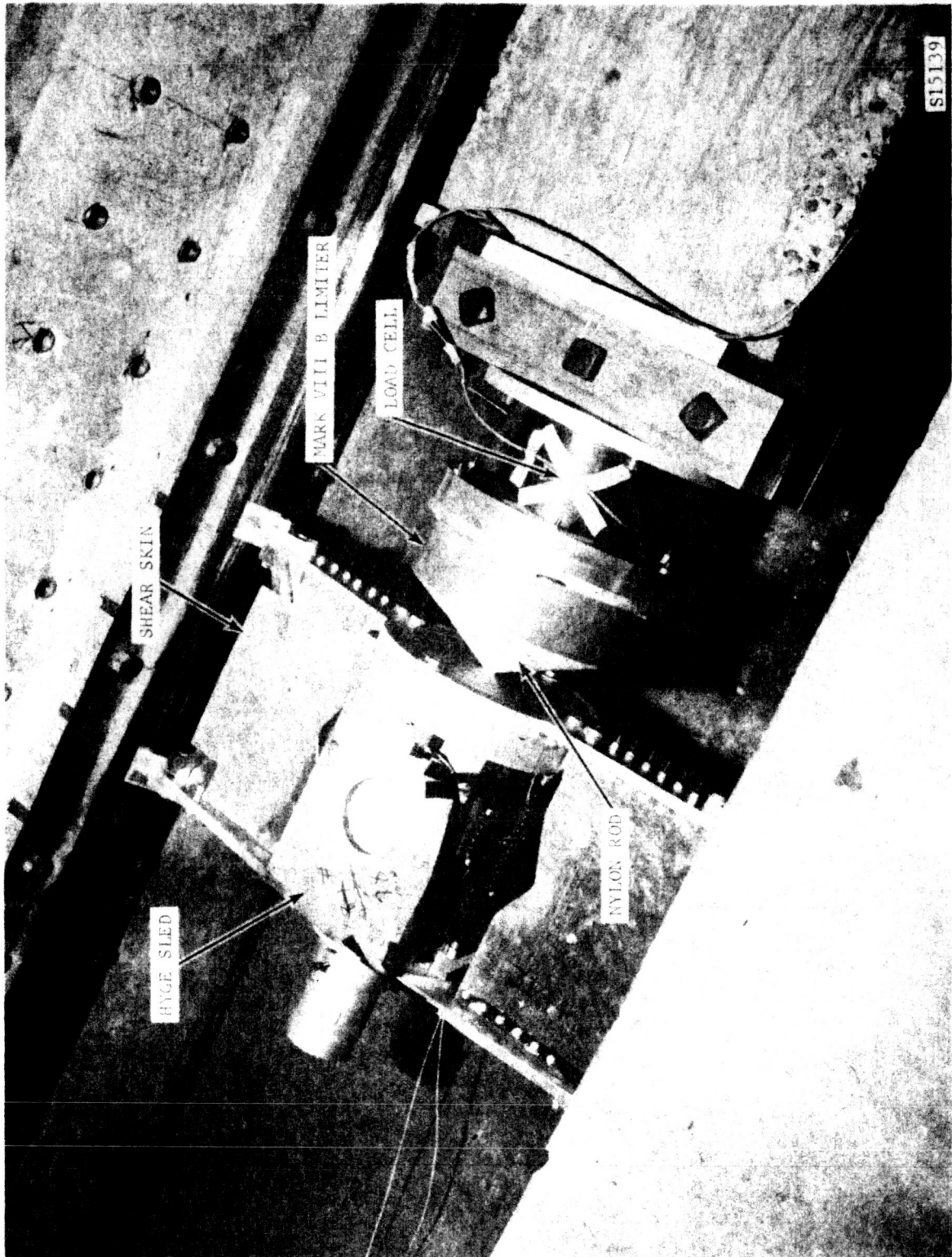


FIGURE 7. MODIFIED HYGE SLED AND MARK VIII B IMPACT LIMITER

TABLE IV
RESULTS OF SLED TEST INSTRUMENTATION

<u>Sled Test No.</u>	<u>Transducer</u>	<u>Sled Velocity, ft/sec</u>	<u>Peak Deceleration, g</u>
1	Photo cells	192.3	-
1	2215 Accelerometer	386	5720
1	Load cell	172	3110
2	Photo cells	182	-
2	2215 Accelerometer	353	5400
2	2225 Accelerometer	166	2920
2	2225 Accelerometer	175	2870
2	Load cell	164	2740

indicated g levels approximately 1.8 times greater than the other instrumentation. Integration of the pulse shapes should be equal to sled velocity. The pulse shape integration of the load cell and the 2225 accelerometers data give values within 10 percent of the actual input velocity. It is evident that these devices are measuring close to actual g values while the 2215 accelerometer does not appear suitable for recording shocks of large magnitude.

SECTION 4

SUBSYSTEMS

4.1 TOP TUBE ASSEMBLY

Progress on the top tube development program during this reporting period is measured in terms of the arrival of components and the completion of several preprototype tests. Parts and components of the developmental and first prototype assembly are being received behind schedule. Of the nearly 170 pieces ordered, little more than 30 percent have been received or manufactured. The parts received are of the small isolated variety so that commencement of the assembly is still awaiting the arrival of major components.

Among the parts thus far received are the motors and gear boxes for the top tube and azimuth drive mechanism. Early in the program it had been decided that based on the knowledge then available of battery capacity and top tube thermal balance, the motor power consumption should be minimal consistent with reliable operation. Consultation with the motor vendor revealed that the power consumption could be reduced to as low as 3.5 watts per unit which is less than the 5.0 watts originally specified for preprototype motor power. Consequently, motors of lower power rating were ordered.

Unfortunately, upon receipt of the new motors it was evident that the above requirement when compounded with the requirements for larger bearings and special lubrication of the bearings with low vapor pressure silicon oil, was found to seriously reduce motor output performance. The gear box input torque is approximately 0.001 ounce-inch and where 5 watt motors produce 0.05 ounce-inch the new motors are capable of only 0.006 ounce-inch at synchronous speed. Any small

interruption by foreign material or additional lubricant in one of the motor bearings easily absorbs this margin. These torque measurements have been obtained with the present breadboard power supply which furnishes a 12 volt square wave from a simulated 30 volt LFC battery.

Several approaches are available to overcome this problem. For the first prototype test series, motor modification would now be impractical. Considerable improvement can be obtained, however, by slightly increasing the power to the motor, changing the input from a square wave to a sine wave and balancing the power input to each of the motor windings. This latter action will require that the resistive loss accompanying the capacitive reactance in one line be balanced in the other line. Since capsule battery capacity and top tube heat balance parameters are now more firmly defined, it is possible to relax the power requirement. Modification of the breadboard motor drive electronics can be readily made to supply the new wave form for the first prototype tests. For subsequent tests, motors wound to draw up to 5 watts of power from balanced 9 volt rms sine wave input will be ordered.

The original preprototype top tube has been tested during the reporting period. A nickel plated cam was installed, the entire system cleaned and all moving parts lubricated with GE F-50 low vapor pressure silicon oil. The assembly was then mounted in a high vacuum tank and operated for 30 hours in less than 10^{-7} mm Hg with one of the viewing windows removed. Although the inside of the tube was exposed for an abnormal period of time to high vacuum, it operated satisfactorily and showed no sign of excessive wear attributable to the test.

Impact tests have been conducted on the nickel cam surface and it has been found that ample margin is available to protect the cam surface from deformation by the cam followers during landing impact. The preprototype top tube has been subjected to impact using the sled and Mark VIIIB HYGE impact limiter. Although the vertical scanning mechanism was originally designed to be caged during impact, the caging device was omitted during this test. Also, components of the scan system were not counterbalanced to prevent angular acceleration during impact; the prototype units are designed to be counterbalanced. Even so, there was no evidence of damage to either the cam followers, the cam or gear box due to impact. The bearings of the motor, though, which had previously survived two preprototype impact tests were partially damaged. This motor did not include the larger bearings and therefore should not be considered necessarily indicative of a potential problem with the prototype design.

The tubular fiberglass spacer which supports the load from the majority of the internal parts of the top tube during impact and also insulates the sensors from the motor heat has been reviewed for structural reliability. The compressive load on this part is such as to require the use of an oriented fiberlaminated epoxy fiberglass. Compressive tests have been conducted on tubular sections and it has been concluded that considerable margin of strength is present.

Tests are now being scheduled for measuring scan accuracy, to impact the new motors and gear boxes and to comparatively measure the reflectance of glass and metal mirrors. An Optron 701 tracker has been ordered and when it is received will be used to record the motion of the top tube cam followers independent of the optical system. After motor and gear box assemblies are tested for smoothness of operation, they will be subjected to vibration and impact on each of two axes. They will then be retested for operational smoothness to determine if any damage is incurred.

It is intended that the mirrors in the scanning system will be plated directly on the cam followers. However, since there is a possibility that plated metal mirror performance may be inferior to that of glass mirrors a test has been scheduled to determine their relative directional reflectance. During this test, the collimated source will be reflected off the mirror surfaces onto a silicon photoelectric transducer similar to the type used in the top tube. The reflected light levels will then be compared with that obtained from direct impingement of the beam onto the sensor.

The LSX-511 light sensors which have been selected were described in the previous bimonthly report. During the past reporting period, these sensors were received and tested. Test results indicate that the sensor is satisfactory both electrically and mechanically.

The pinholes which are mounted directly onto the active surface of the sensor are within specified tolerance and are well defined. A microphotograph of an LSX-511 surface with pinhole is shown in Figure 8. Tests indicate that all cells are sensitive only within the unmasked region. The diameter of this area varies from 0.0057 to 0.0061 inch. These measurements were performed with a micropositioner and microscope to within an accuracy of ± 0.0001 inch. The depth of the pinhole below the flat window of the sensor case was measured and found to average 0.020 inch with maximum variation of ± 0.005 inch for most of the sensors.

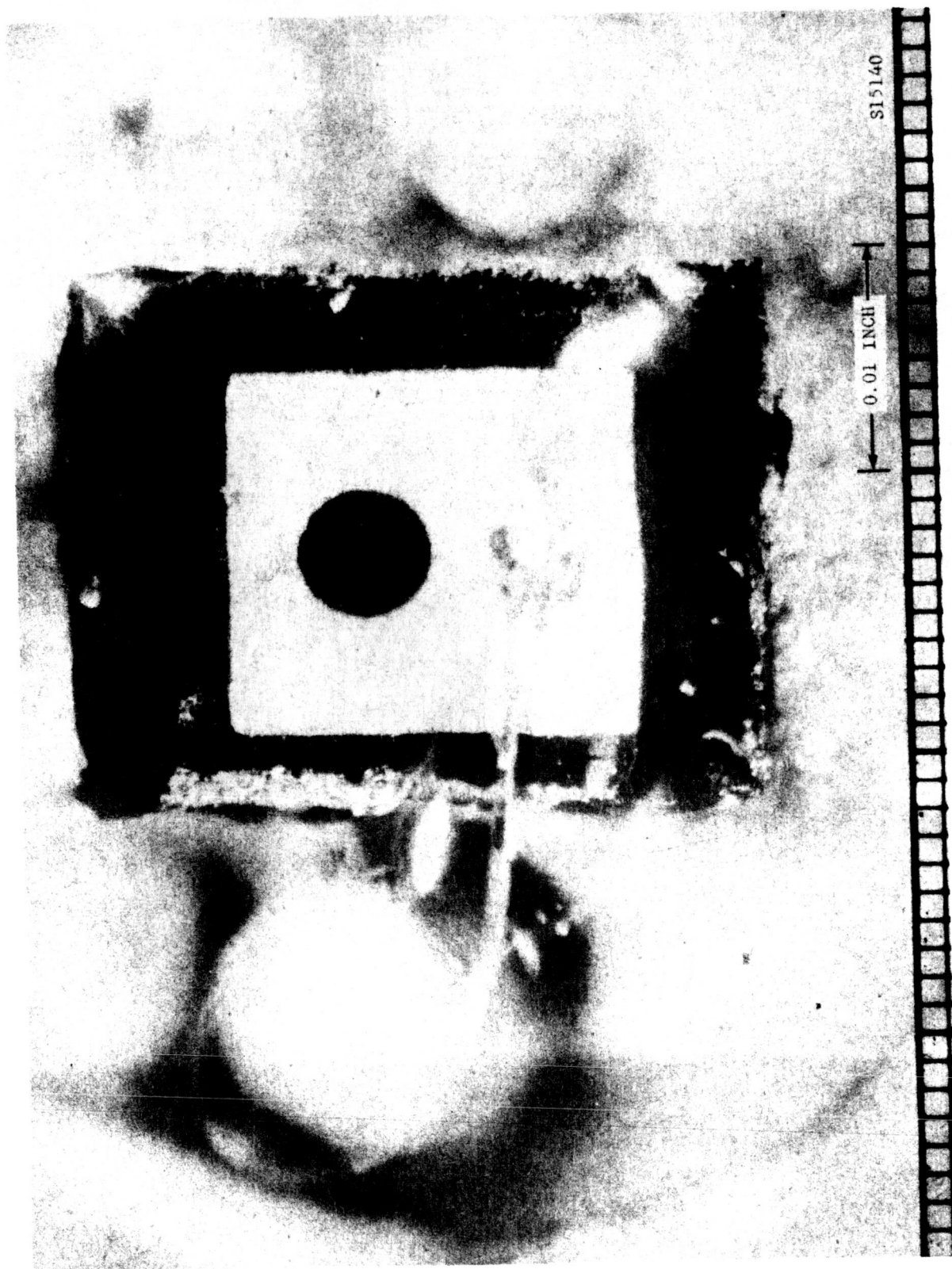


FIGURE 8. MICROPHOTOGRAPH OF LSX-511 SENSOR WITH INTEGRAL PINHOLE

Sensitivity tests were performed on five units by the method described in previous reports. The detectivity of these units was found to vary from 5.43×10^{11} to 8.42×10^{11} cm-cps²/watt. These values are a significant improvement over that which was measured with the LS400 sensors with an externally mounted pinhole. With the improved detectivity of the LSX-511 sensors, the typical rms signal-to-rms noise ratio of the sensor/preamplifier at low light levels (25 foot-Lamberts) is somewhat better than 19 db.

The capacity of the sensor has increased by at most $1.3 \mu\mu\text{f}$ from the value before masking; however, this has not resulted in any significant change in performance. All other characteristics of the sensor are approximately the same as those of the LS400 sensor.

The sensors now being used in the LFC program are actually NPN Planar Silicon Transistors without a base connection. As such, they may be considered to be less than optimum for this application. Tests have indicated that their performance can be made more linear and the dark current may be reduced by about a factor of 10 by omitting the emitter diffusion process during fabrication. Further, it has been shown that the response to blue wavelengths can be improved by altering the device geometry. It is believed that this may provide an increase in signal-to-noise ratio by as much as 3 db, as well as rendering the resulting picture more familiar to the human eye. Raising the circuit impedance by scaling the device down to the required size instead of masking unused areas, improving the sensor packaging, redesigning the preamplifier input transistors, and possibly even functionally integrating the preamplifier and sensor operations can theoretically yield another 10 db of signal-to-noise ratio improvement.

The electrical design of the preamplifier has remained unchanged since that reported previously. Effort during this reporting period has been concerned with packaging the two preamplifiers in the small volume available in the top tube (See Figure 9). An initial packaging attempt has caused:

- (1) an increase in input capacity as a result of the high dielectric constant of the epoxy used to mold the module, and
- (2) cross-talk between preamplifiers because of their close proximity and their high sensitivity associated with very high input impedance.

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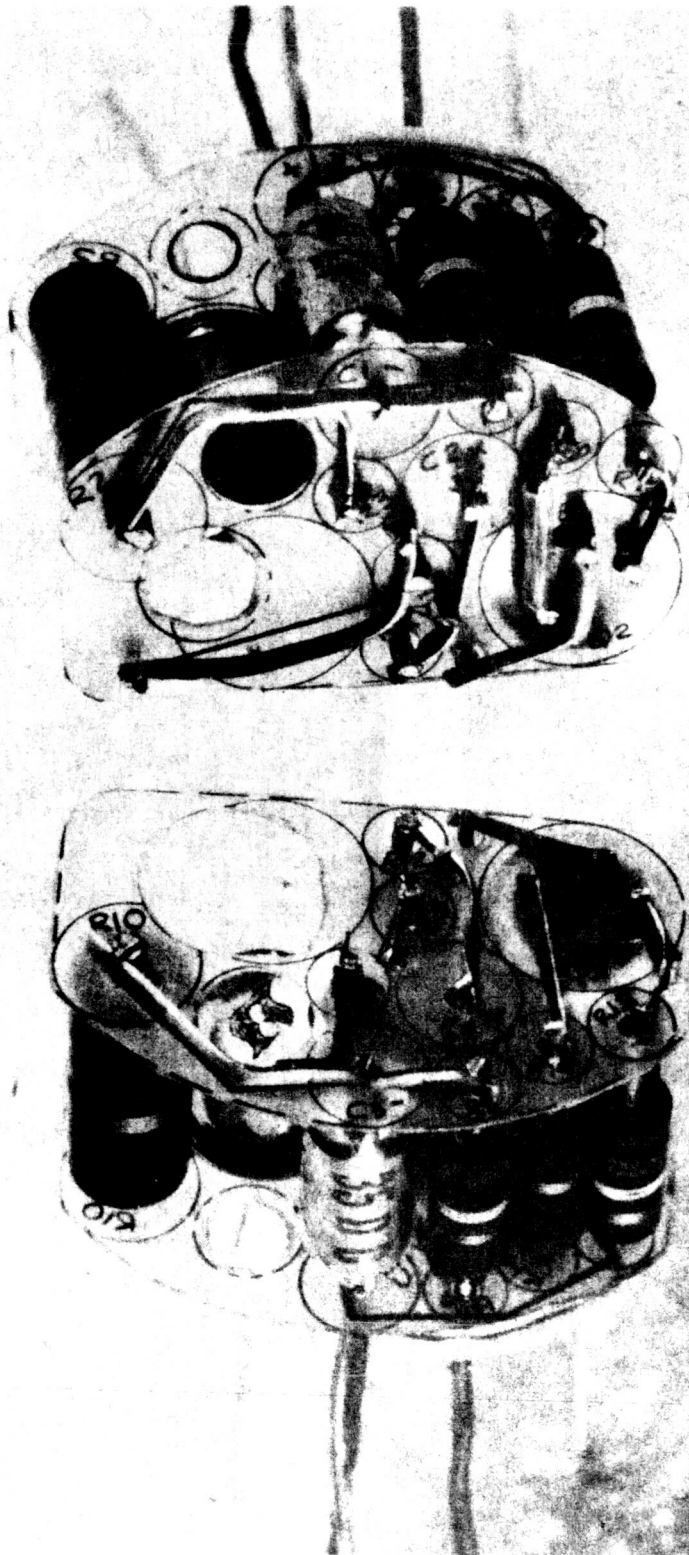


FIGURE 9. UNPOTTED DUAL PREAMPLIFIERS, LESS SENSORS

Redesign of the package to eliminate these problems has been completed, and a model is currently being fabricated to test these characteristics. The capacity of the circuit is being minimized by use of a filled casting resin with low dielectric constant and the two preamplifiers are now completely shielded from one another to eliminate the cross-talk problem. The two preamplifiers are still contained within a single plug-in module and no increase in module dimensions have been required for the redesign.

Sled tests to determine impact capability of various electronic components were performed during this reporting period. No change in device characteristics were noted on any of the items tested. The items which were tested are shown in Table V.

4.2 AZINUTH DRIVE MECHANISM

During this reporting period, design of the first prototype azimuth mechanism incorporating the helical worm gear drive was completed. Figure 10 shows an exploded view of this assembly. Prior to release of final drawings for fabrication of this assembly, a final design review was conducted. As a consequence of this review, certain items of significance were investigated as discussed below.

The design specification was revised to allow for 0.03 degree rotation of the azimuth tube about an axis in the equatorial plane of the payload for an applied transverse load of 0.2 pound. This rotation is allowed by the diametral clearance present in the azimuth journal bearings. It is not considered detrimental since:

- (1) horizontal loads are not anticipated during operation. In their absence, rotations about other than the central axis will not occur.
- (2) A rotation of 0.03 degree about an axis in the equatorial plane of the payload results in only 0.010 inch horizontal motion of the viewing window. At the distance from the window to near field objects (39.4 inches) this represents less than 0.02 degree (1/5 of an image point).

It has been noted that a failure could occur by over torquing the nut used to adjust and retain the helical worm gear shaft and bearings. This would result in a sizable axial preload to the bearing set

TABLE V

ELECTRONIC COMPONENTS FROM TOP TUBE ASSEMBLY WHICH
WERE IMPACT TESTED DURING THIS REPORTING PERIOD

<u>Item</u>	<u>Type</u>	<u>Manufacturer</u>	<u>Number</u>	<u>Approximate Deceleration, g</u>
Sensors	LSX-511	T.I.	2 ea.	2800
Transistors	2N2606	Siliconix Field Effect	5 ea.	3100
	2N930	T.I. Silicon	5 ea.	3100
Capacitors	1 uf 35v	Sprague 150 D Tantalum	3 ea.	2800
	0.47 uf 35v	Sprague 150 D Tantalum	3 ea.	2800
	1 uf 35v	Sprague 155 D Tantalum	4 ea.	2800

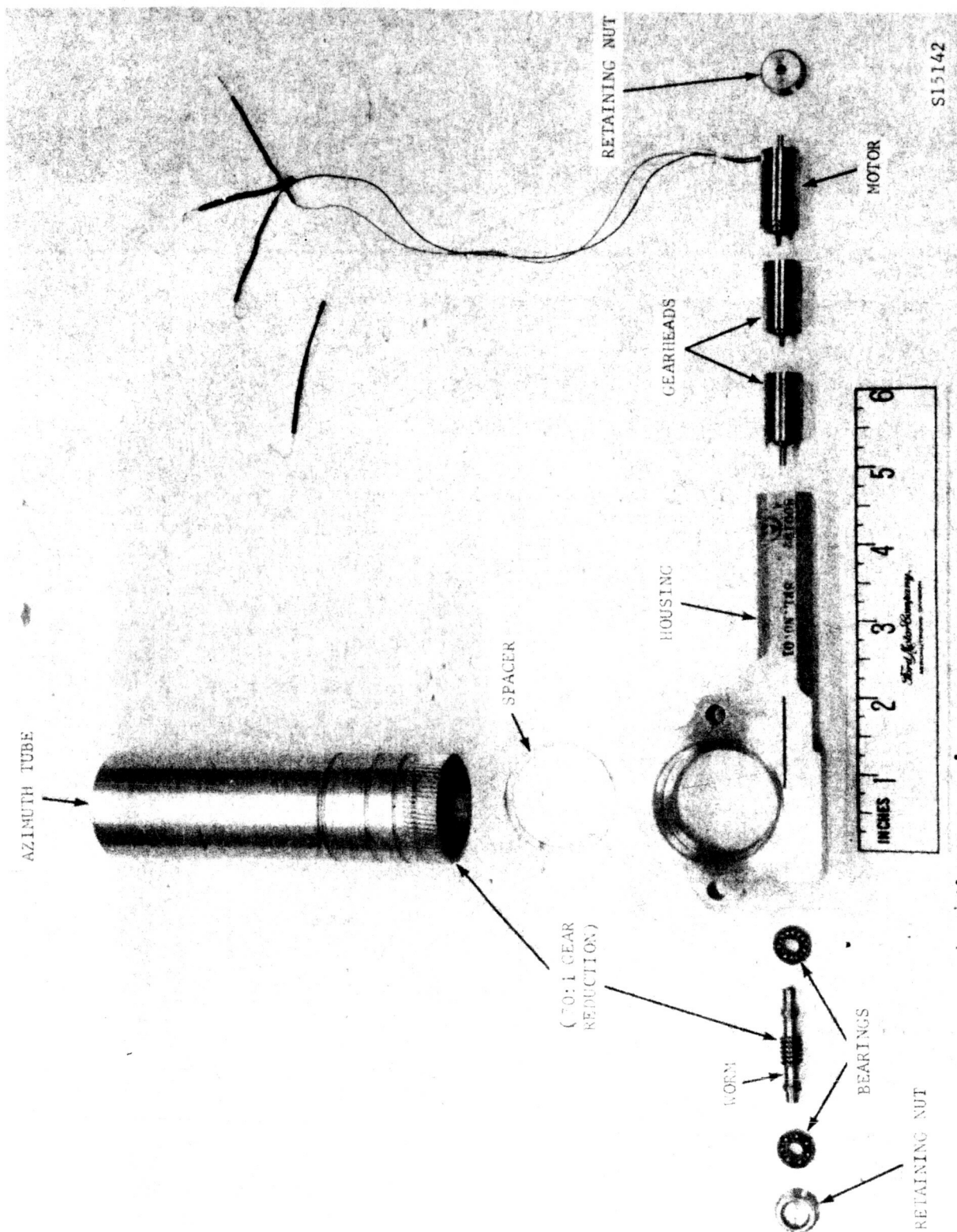


FIGURE 10. EXPLODED VIEW OF AZIMUTH DRIVE MECHANISM

which would in turn, reduce the bearing capacity. It could even be reduced so much so that it would be unable to support axial impact loads. Alternative designs which precluded this possibility have been investigated. However, all have proven unsatisfactory since they do not provide the necessary axial adjustment of the bearing set required to eliminate axial and radial bearing play. Therefore, a detailed assembly procedure has been prepared to provide assurance that axial preload is not imparted to the bearing set.

A possible failure mode has been found to exist in the small size 5 gear head shown in Figure 11. The spur gear might slip on the shaft. The spur gears are pressed into position on their respective pinion shafts. The smallness of the shaft does not allow the spur gear to be staked and since pinion teeth must be hobbled on the shaft adjacent to the spur, the shaft cannot be cut from a single piece. Since under a 3000 g impact the spur gear weighs approximately 1 pound a test was conducted to determine the force required to initiate slippage. Results of tests on four samples showed this force to exceed 20 pounds. Although this high margin of safety existed for the units tested, there is no assurance that the suppliers assembly process would provide the same integrity in all units. Hence, an in-process acceptance test requirement has been written for inclusion into the design specification.

Provision has been made for venting the capsule following extension of the top tube. The benefits of this are:

- (1) the possibility of lifting the driven azimuth tube axially due to internal pressure is eliminated (since the gear set tends to drive the tube down to its natural position, lifting could result in axial chatter),
- (2) the complete absence of air obviates the concern regarding partial depressurization of the sphere due to leakage and the possible consequences of corona in the transmitter.

The top tube wiring bundle has been wound such that the torque it exerts will not reverse direction during top tube rotation. This precludes the possibility of the top tube wiring causing undesirable backlash in the driving azimuth tube.

Three azimuth drive subassemblies have been fabricated. These units will be used for engineering functional tests, subassembly impact tests and first prototype landing sphere tests. These tests are scheduled to be conducted in the succeeding report period.

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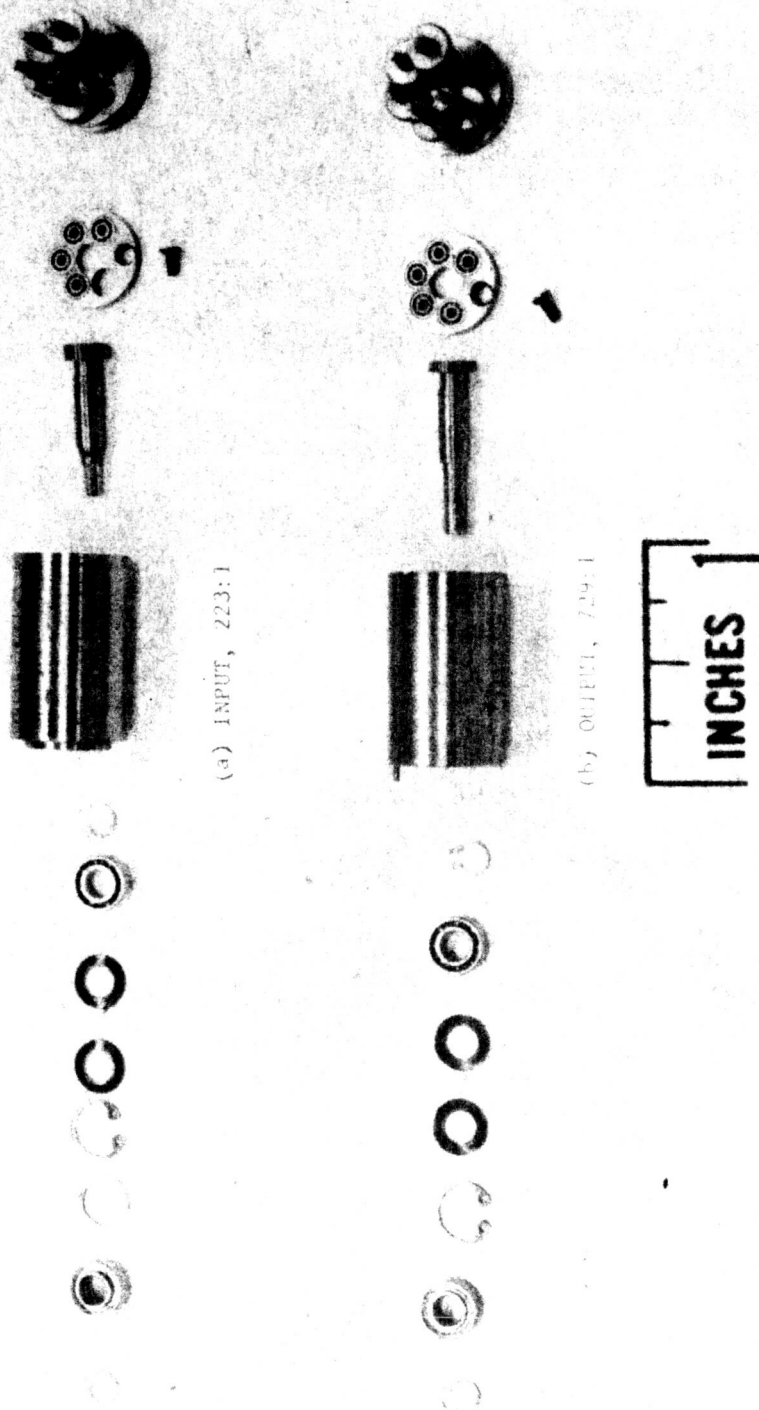


FIGURE 11. SIZE 5 GEAR BOXES USED IN AZIMUTH DRIVE ASSEMBLY

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Early in the present reporting period, the motor/gearhead combination was subjected to a lateral impact in excess of 3000 g. Functional tests performed prior to and following impact indicated no deterioration of performance. Additional impact tests of these components are being scheduled.

4.3 EXTENSION MECHANISM

During this reporting period, a Design Review was conducted and the design specification was upgraded. Development test hardware and associated fixtures have been fabricated and assembled. (See Figures 12 and 13). Procurement of prototype No. 1 hardware is nearly complete.

The engineering developmental extension system (Figure 13) has been assembled, checked out and preliminary tests conducted. The set-up provides for evaluating the effect of control orifice size and capsule gas volume. Extension velocity, extension pressure, and top tube shock are also instrumented to allow for performance evaluation. Preliminary results indicate that the range in extension velocity of 2 to 11 feet per second determined from the functional model tests is also valid for the full-size system. Tests are continuing to establish the proper control orifice diameter and the effect of variation in available gas volume. Tests have demonstrated that the top tube wiring bundle does not tangle when extended after recycling.

Prototype No. 1 will be vented immediately upon extension to eliminate prolonged axial loading of the azimuth drive bearings and to prevent passing through possible arcing pressures during transmitter operation. The venting is accomplished through a 1/32 inch diameter hole in the extension tube and leakage past the snap ring joints. Should it subsequently be decided that pressure integrity be required after extension, the vent may be eliminated and a lip seal or other low friction seal system developed. Buna-N and Viton-A "O" Rings with special lubricants have been evaluated and found to give unreliable action and excessive drag. Conventional types of lubrication required for smooth operation of "O" Rings may not be used as the oil film would degrade the radiation characteristics of the surfaces of the extension and top tubes. Consequently, "O" Rings will not be used.

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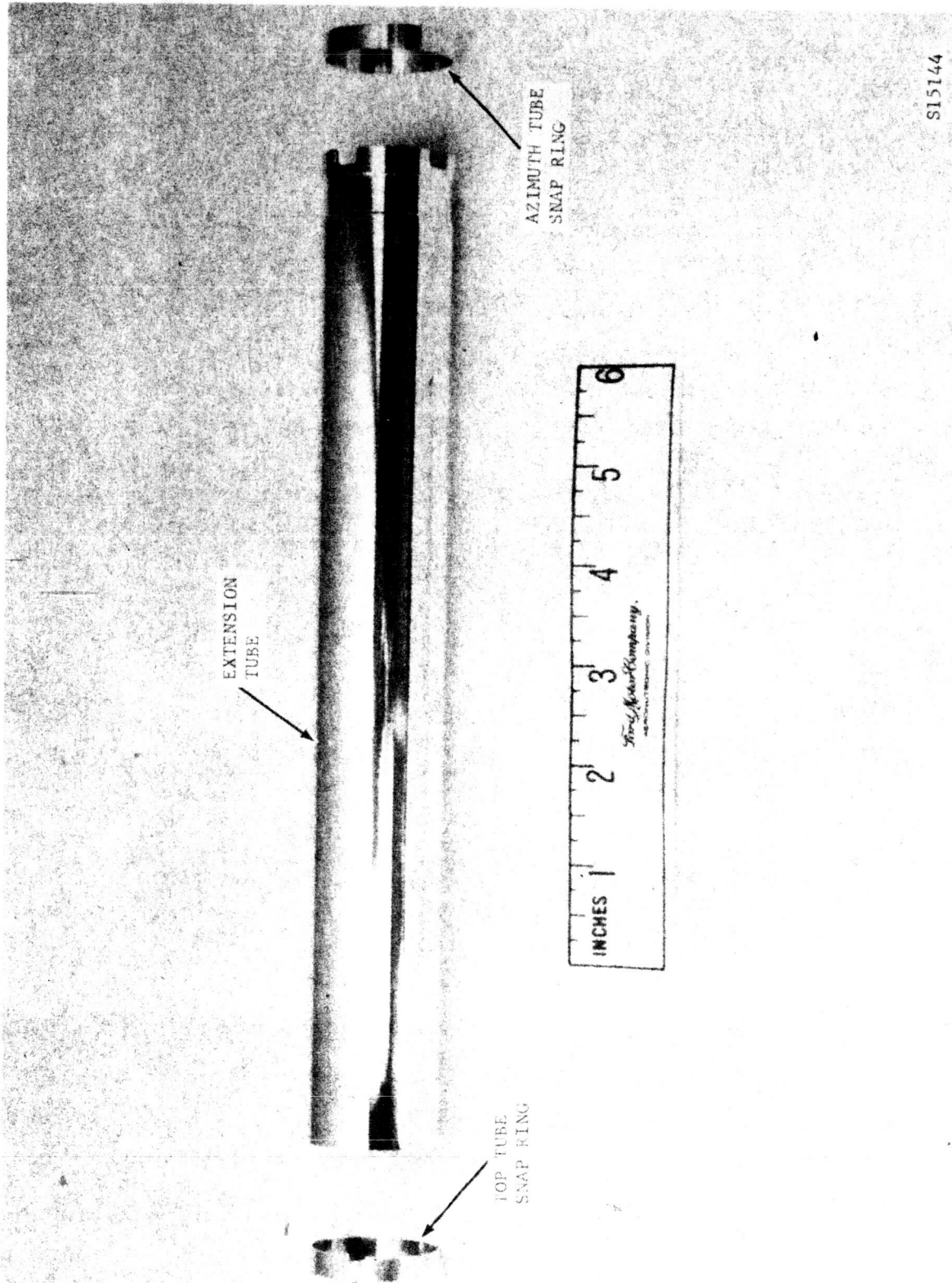


FIGURE 12. PROTOTYPE EXTENSION MECHANISM

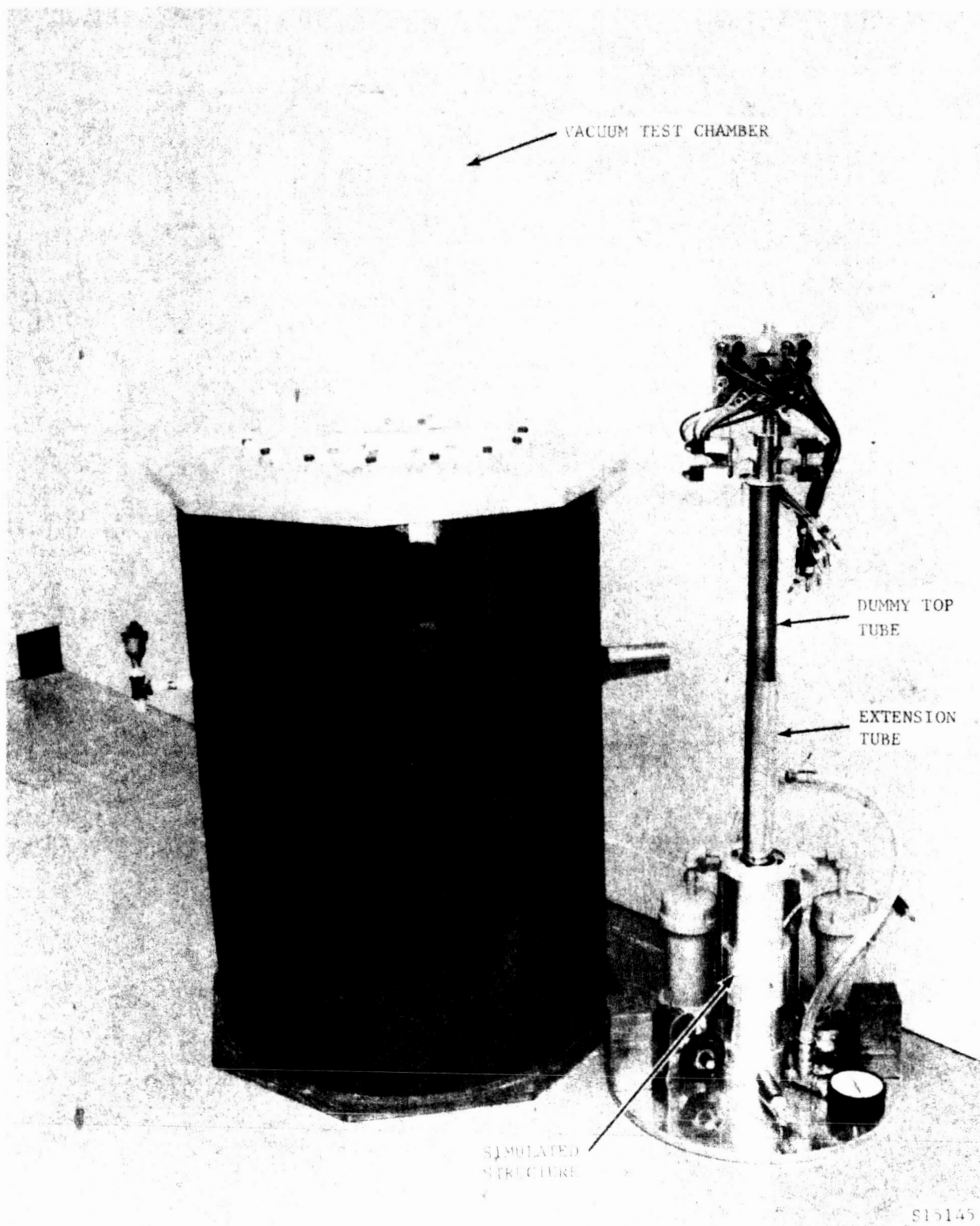


FIGURE 13. DEVELOPMENTAL EXTENSION SYSTEM AND TEST ASSEMBLY

4.4 STRUCTURE

All drawings for Prototype No. 1 have been released and fabrication has been initiated. Final machining operations have been completed on the first two sets of braze assemblies. The schedule for the braze structures had temporarily slipped as a result of an unsuitable fit between the basic structures and the outer shells. This problem has now been solved. All additional structural elements, such as dummy components, battery cover plates, coupling rings, etc., have been fabricated and are available for fit check and installation (See Figure 14).

A Design Review of the first prototype payload structure has been conducted. Mention was made at that time of using the electron beam process as a means for welding shut the draining and inspection ports after the final brazing operation to avoid producing excessive distortion. Results to date are still inconclusive and complete evaluation of this process would necessitate further testing with this tightly scheduled device, which does not appear compatible with the program schedule.

An inquiry has been made into an electrolyzing process to determine its utility in preventing deleterious effects such as galling action between aluminum parts, especially at threaded joints. Electrolyzing is a proprietary process which is primarily a deposition of a hard chromium plate onto parts requiring protection. Subsequent to this investigation, it was decided that a chromium/chromium couple is not as desirable as a cadmium/cadmium nickel interface. The latter will be used on the threaded cap of the lower braze assembly.

The structural gussets within the electronic compartment of the upper braze assembly are no longer necessary since the electronic packaging design provides structural boxes with end plates. These gussets will be eliminated from future structures simplifying the machining operation.

A structural analysis of the dummy transmitter has been performed to determine the stress levels and critical zones of the housing and to predict deformations which may occur during impact. The results indicate a satisfactory margin of safety of approximately 120 percent. The expected deflections are 0.024 inch for the battery cover plate subjected to the weight of the batteries during impact and 0.0012 inch radially at the thinnest section of the outer wall of the transmitter housing should the peak impact pressure occur in that general vicinity.

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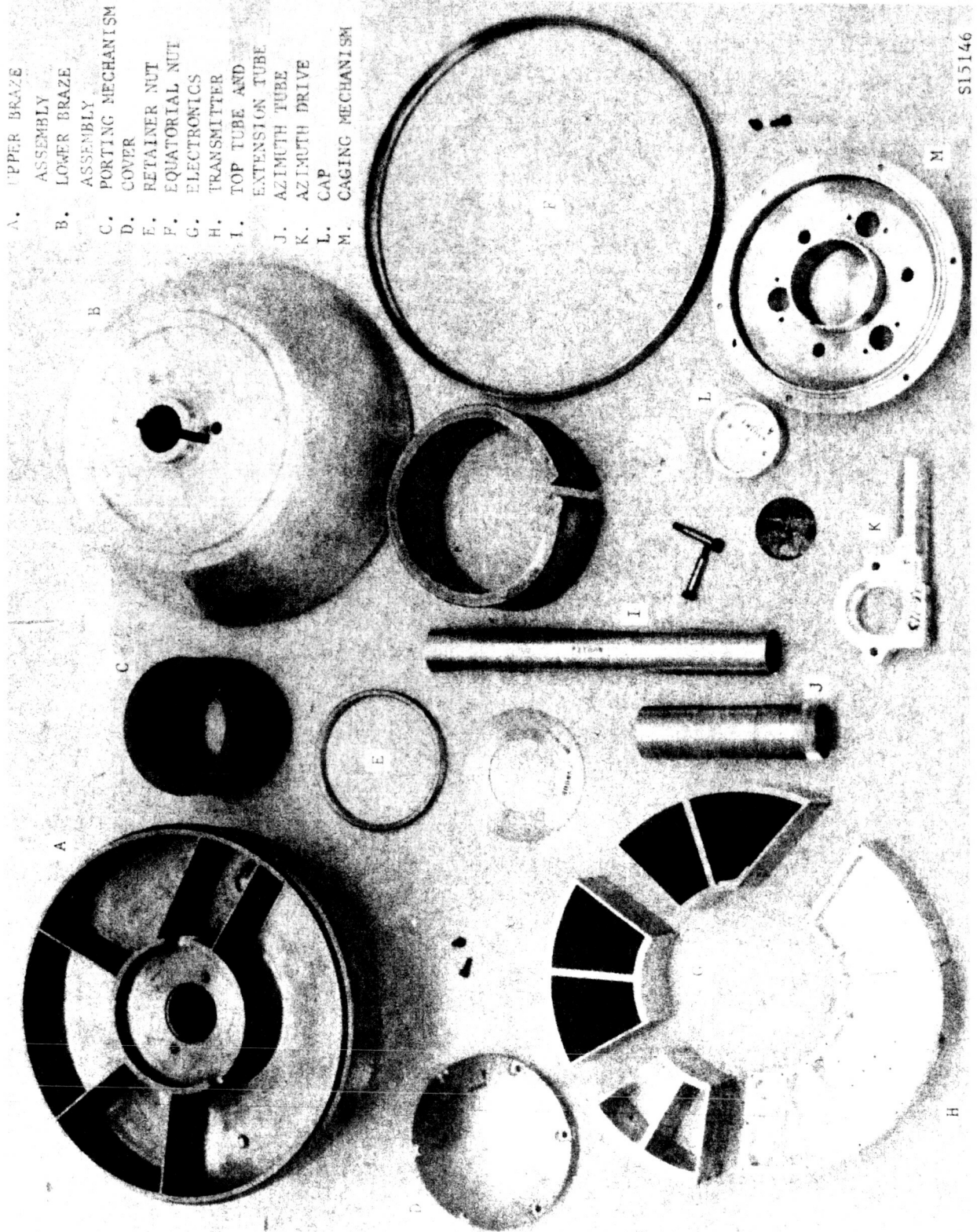


FIGURE 14. BREADBOARD PAYLOAD STRUCTURE WITH DUMMY SUBASSEMBLIES

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The design of the payload structure includes the use of "O" Rings made of Buna-N rubber material. These "O" Rings come into intimate contact with the flotation fluid and hence the choice of material is of vital concern. A test is now in progress to determine the effects of long time immersion in flotation fluid. Present data thus far appears to justify the use of Buna-N.

4.5 SIGNAL AND SYNCHRONIZATION ELECTRONICS

An informal Design Review has been held on the signal electronics at which time the design and performance characteristics were reviewed. A breadboard has been completed and tested and meets all requirements of the design specifications.

A system compatibility test of the signal electronics with the sensor/preamplifier is now being conducted. Figure 15 displays the overall response of the signal electronics to a chopped DC input. In the synchronous demodulation mode, 45 db dynamic range has been achieved with good linearity. The demodulator is fail-safe against loss of the reference signal by functioning as an envelope detector. Performance is degraded but useful picture detail would still be transmitted.

A simplified signal electronics circuit has been conceived which will eliminate a significant number of components to potentially increase overall reliability and minimize size, weight and power consumption. This new circuit is being tested and evaluated to determine how well it meets performance requirements for the signal electronics.

4.6 MOTOR DRIVE ELECTRONICS

An informal Design Review has been held on the motor drive electronics at which time the design and performance characteristics were reviewed. A breadboard has been loaned to the motor manufacturer. It now appears that some redesign will be required to supply higher power, sinusoidal waveforms and balanced outputs. This effort is currently in progress.

4.7 GROUND REPRODUCTION SYSTEM

The breadboard ground reproducer reconditioning task covers three areas of interest. These areas consist of the mechanical, electronic, and optical subsystems of the unit (See Figure 16)

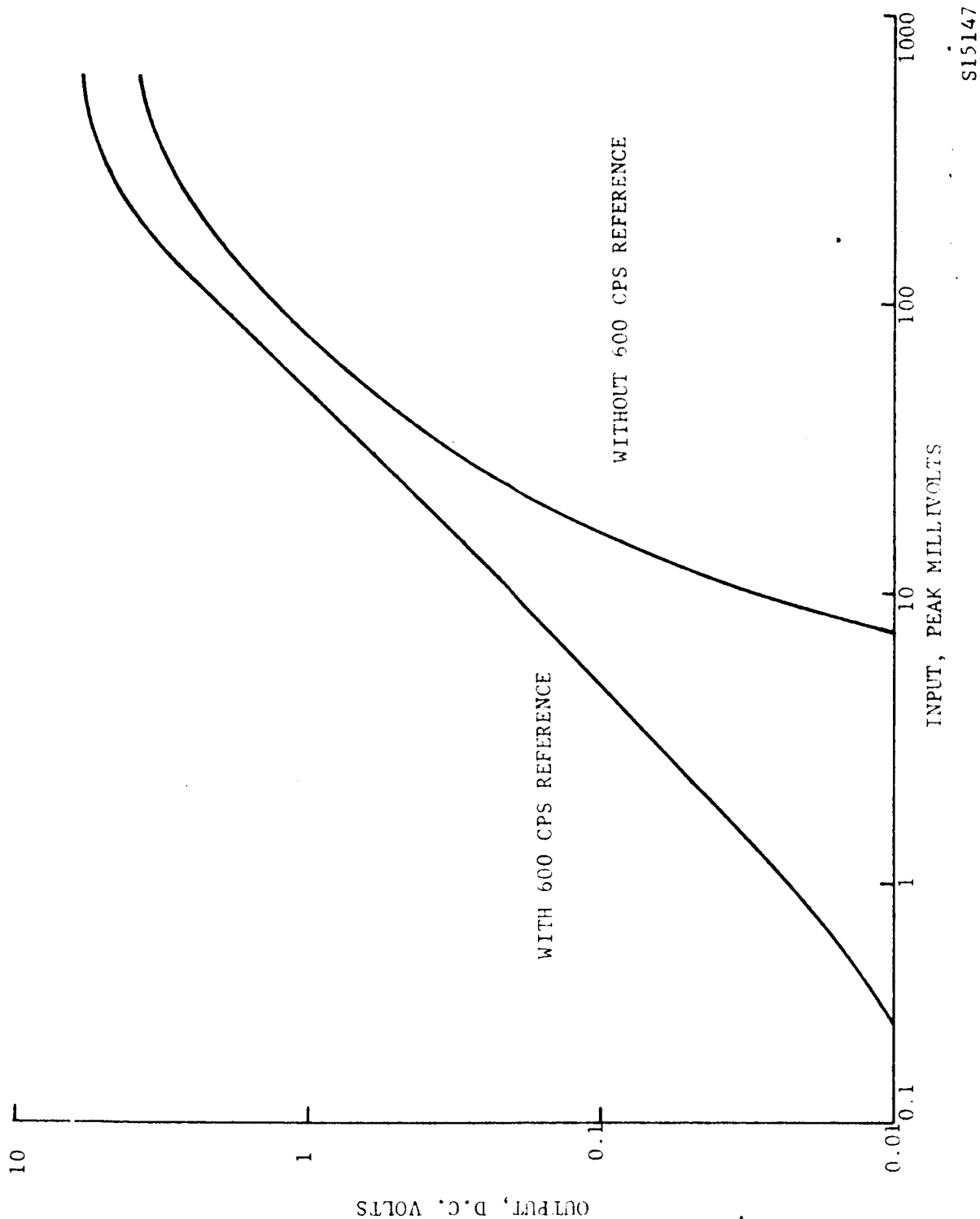


FIGURE 15. SIGNAL ELECTRONIC OUTPUT VS INPUT FOR CHOPPED DC SIGNAL

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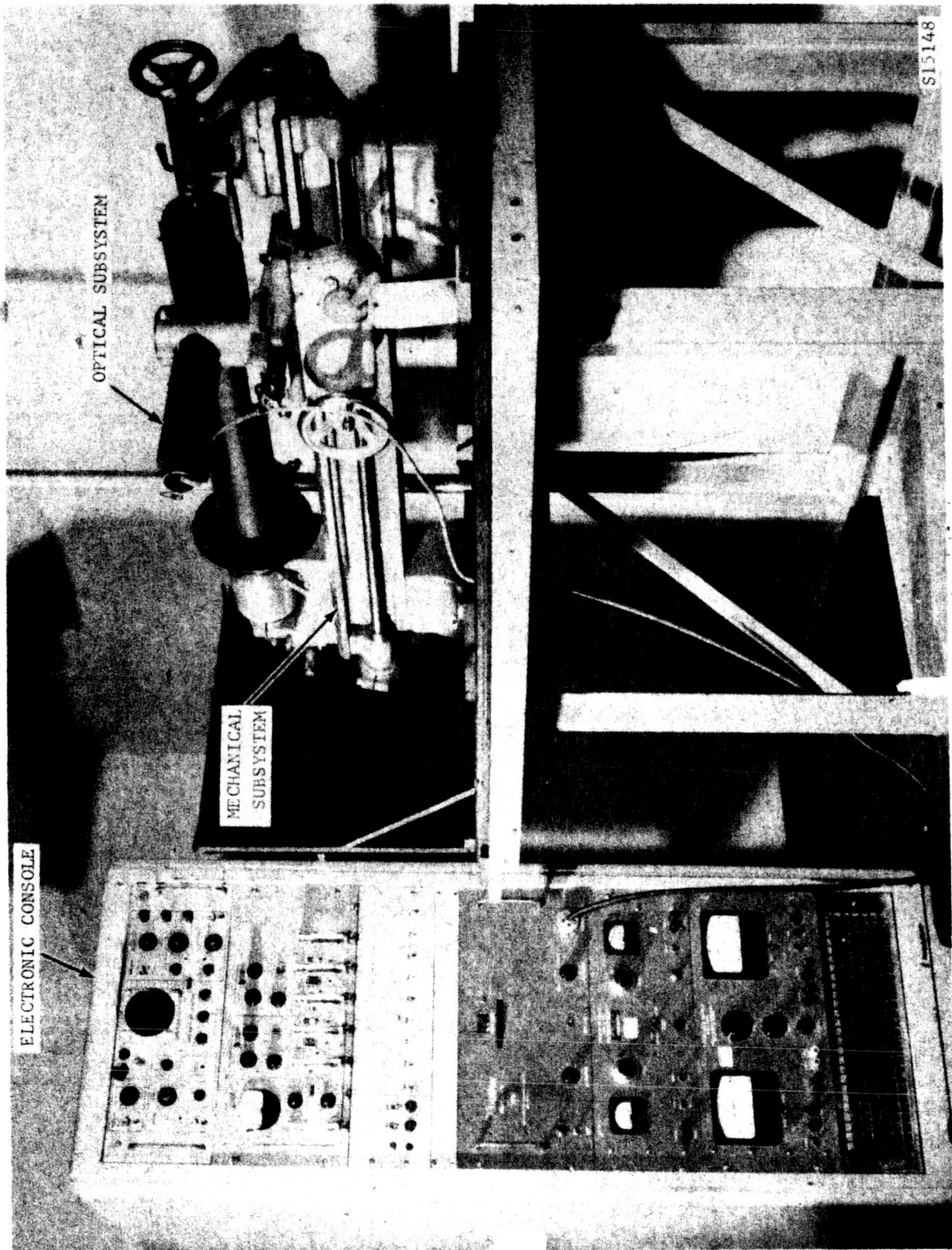


FIGURE 16. BREADBOARD GROUND REPRODUCER

The film drum drive mechanism, as originally redesigned, consisted of a 400 cycle per second, 8000 rpm hysteresis synchronous motor driving the drum (and lead screw) through a 2160:1 speed reduction. The 2160:1 ratio was to be accomplished by the technique shown in Figure 17. The 2:1 bevel gear, combined with the 36:1 spiroid/worm gear, were specified to replace the 72:1 speed reducer previously used. Ideally, the smooth action of the worm gear would eliminate chatter and noise due to spur gear teeth engagement in the 72:1 speed reducer. (It is believed that noise was introduced through the drive and lead screw since it was found that bearings eliminated the sliding friction of the shaft.)

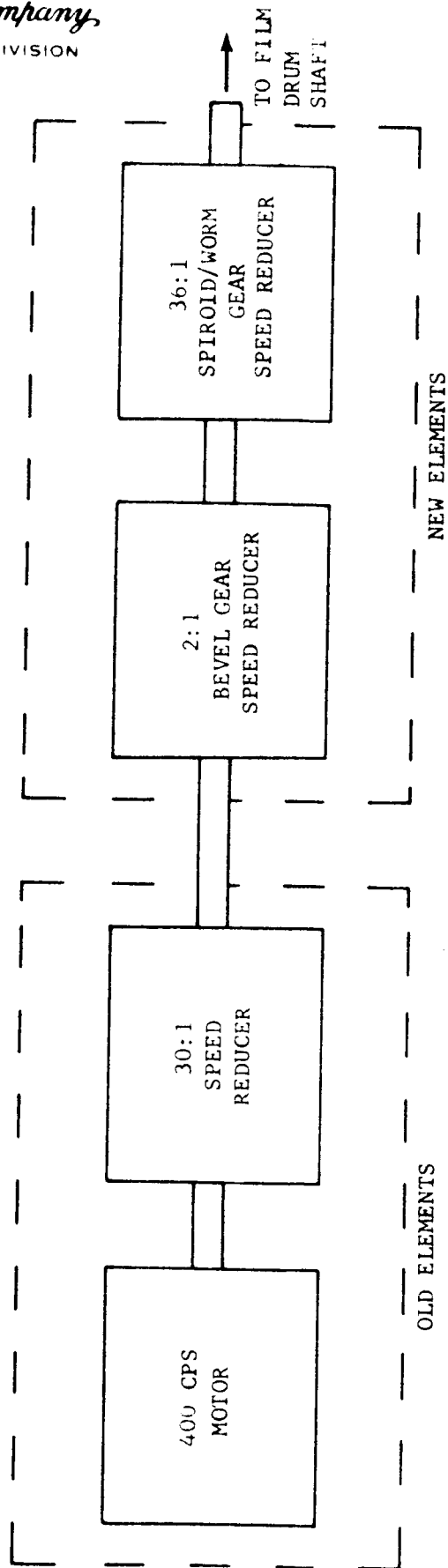
These gears were purchased and assembled in accordance with the design, however, system operation indicated that film drum "chatter" was still of objectionable magnitude due to the fact that this vibration could be visually observed. Therefore, a more detailed analysis of the problem was instigated.

A strain-gage accelerometer was installed on the film drum to measure the frequency and amplitude of the "chatter" components. This instrument was A.C. coupled to an amplifier and recorder in such a way that the 1 g field due to gravity did not saturate the recordings. This data was utilized in determining the operational effects of system modifications that were incorporated in improving the smoothness of drum rotation. Frequency data was used to indicate the chatter generating components.

The "new elements" (2:1 bevel gears and 36:1 spiroid/worm gear) were removed and the 72:1 speed reducer was reinstalled. The output shaft of this unit drives the drum shaft through a mechanical coupling. This coupling was replaced by a heavier coupling to eliminate torsional "wind-up" that may have been occurring in it. Also a heavy coupling with a laminated leather mid-section was tried. This type of coupling acted as a low-pass filter and does not easily couple high frequency components of vibration from the drive mechanisms to the drum shaft. (It was soon determined, however, that this coupling offered negligible improvement and subsequently was not used.)

Two methods of approach were attempted and the salient features of each are listed below:

- (1) Obtain a system of high natural frequency.
Low frequency perturbations in the input drive would then not be amplified by the system regardless of damping factor.



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FIGURE 17. BLOCK DIAGRAM OF GROUND REPRODUCER MOTOR DRIVE

- (2) Obtain a system of low natural frequency.
All spurious and unwanted perturbations
above this frequency would then be
attenuated.

The second of these two methods was attempted first. For any system whose transfer function is classified as a quadric log network, the natural frequency f_n , is inversely proportional to the square root of the rotational media, J . Therefore, if J is increased by 100, f_n will be decreased by $100^{\frac{1}{2}} = 10$. Also the damping factor is directly proportional to f_n and would be decreased by the same magnitude under these conditions.

The inertia was increased by adding balanced lead weights to the drum driving disk. This action drove f_n to approximately 10 cycles per second (previously $f_n = 54$ cycles per second).

A film test was made under these conditions. It revealed a sinusoidal amplitude modulation which was apparently due to the 96 engagements per drum revolution of the output gear of the 72:1 speed reducer. This translates into a 5.83 cycle per second fundamental frequency. The 5.83 cycle per second signal is apparently amplified, as the natural frequency could not be driven below 10 cycles per second.

The high frequency condition ($f_n = 54$ cycles per second) was created by removing the lead weights. A second film test verified this since only high frequency chatter components were observed.

As a comparison, the 2:1 bevel gear and 36:1 spiroid/worm gear arrangement was reinstalled in place of the 72:1 speed reducer. A third film test was made and it was noted that the amplitude of the high frequency (16 cycles per second) chatter was greater here than with spur gear drive as used on the second film test. (A low natural frequency condition using this drive could not be mechanized as the spiroid/worm could not handle the greater torque load that accompanies increased inertia.)

It was believed that the results so far obtained could be greatly enhanced if the system damping could be greatly increased through a viscous coupling between the output gear box and the drum shaft. Viscous coupling would produce the required results, but implementation of such an item was considered too much of a problem for this system. Therefore, a viscous drag brake was designed and installed on the drum drive shaft. This brake consists of two

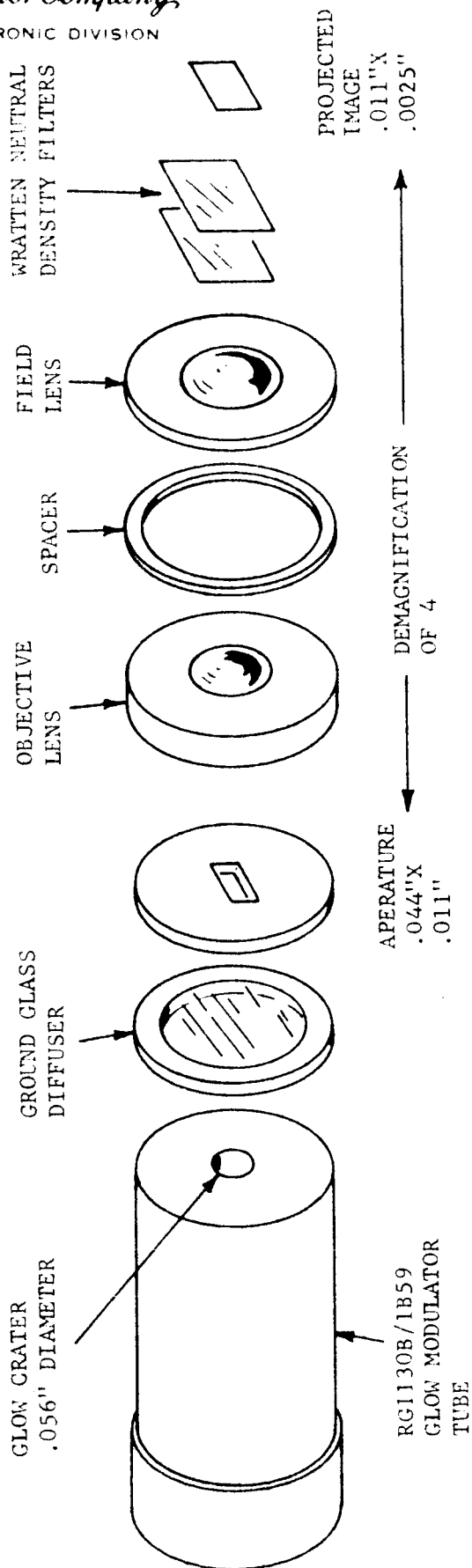
coaxially mounted cylinders. The inner cylinder is fixed to the drive shaft and rotates with it. The outer cylinder is stationary. DC-11 lubricant separates the two units and provides the high viscosity drag. The lubricant is inserted until the brake creates 21 inch-pounds of torque to be seen by the 72:1 speed reducer output shaft. This loading heavily masks the 32 ounce-inches loading of the lead screw and drum.

A fourth film test was made with the viscous drag installed and the lead weights ($f_n \approx 10$ cycles per second) utilized. Amplitude modulation due to gear teeth was almost undetectable.

The 5.83 cycles per second "chatter" that was slightly detectible on the film is apparently due to transmission of the output gear smoothness directly. This smoothness is directly dependent upon the quality and precision of the gear and cannot be improved upon without considerable redesign and run-in. At this point, it is believed that the mechanical drive has been improved sufficiently to satisfy the needs of this task. Therefore, this portion of the effort has been terminated.

The electronics portion of this task was completely finished during the previous reporting period. However, some slight modifications have been necessary to facilitate film testing. These changes were insignificant and will be incorporated into the final schematics when film testing is completed.

The basic optical subsystem, as previously used, is indicated in Figure 18. These elements were assembled in a housing and mounted on the lathe tool carriage which is driven by the lead screw. The unit was disassembled (see previous bimonthly report) and reassembled after all parts were given a dull black finish. However, the aperture size was increased to 0.057" x 0.014". The actual dimensions are not critical (under ideal conditions), but the ratio of the length to width (4:1) is critical. Therefore, it was believed that this increased size would offer no problem. The proper demagnification of approximately 5 could be facilitated by increasing the objective lens-aperture distance until the projected image was 0.011" x 0.0025". But, the ground glass diffuser that was supposed to evenly illuminate the aperture did not function in this manner. Also, the glow crater was not positioned precisely on the center of the tube axis. Therefore, uneven illumination across the projected spot was noticed. Apparently, utilization of a smaller aperture during the original High Resolution Facsimile feasibility study over a year ago, had enabled this problem to remain unnoticed.



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FIGURE 18. FUNCTIONAL DIAGRAM OF ORIGINAL OPTICAL SUBSYSTEM OF GROUND REPRODUCER

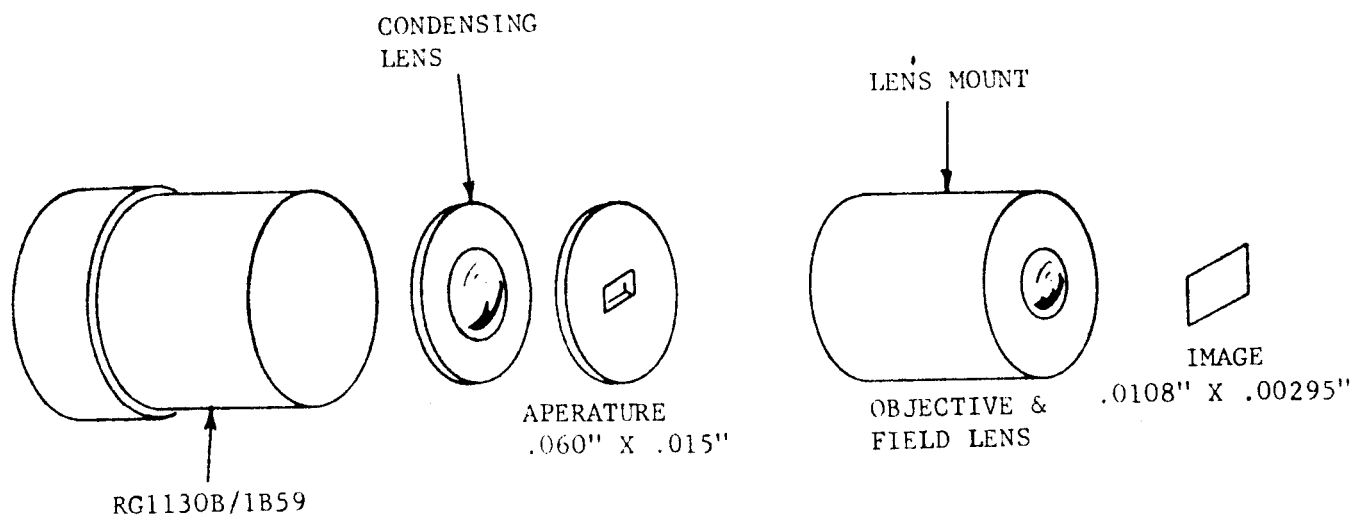
When the diffuser was removed (it does not provide the even illumination required) no effect was noted. The increased light level caused "flaring" of the projected image. This flaring which is thought to be due to defraction of the light by the aperture could not be reduced by adding light baffles or changing objective lenses. The problem was solved (or greadly reduced) by adding a condensing lens between the light source and the aperture. This lens images a magnified reduced level crater onto the aperture. This technique approximates some of the results that would be obtainable from a collimated light source. Also, by placing the glow tube crater inside the focal point of the condensing lens, a uniformly illuminated image is obtained. The optical elements have been re-assembled into the configuration shown in Figure 19.

Other techniques, such as a double imaging system, were tried in an effort to obtain even illumination and several week's time was consumed in experimentation and adjusting. Also, additional lens mounts and baffles were manufactured and given dull black finishes.

The 100:1 dynamic range feature that has been stated as a system goal has justified closer examination of the component parts of the optical system. This examination has revealed the following new facts.

- (1) The red color output of the RB 1130B/1B59 glow modulator is not linear with pulse width.
- (2) The blue color light output of this tube is linear and a 100:1 dynamic range appears feasible.
- (3) Due to (1) and (2), blue filtering with attendant light loss will be necessary due to the panchromatic nature of the film. Also, a major portion of the visible light spectrum lies in the red region and would dominate in an unfiltered situation.
- (4) Due to filtering, increased light levels will be required and "flaring" of the projected image is predicted. (Flaring was undoubtedly present in the previous system, but heavy neutral density filtering reduced

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FIGURE 19. FUNCTIONAL DIAGRAM OF NEW OPTICAL SUBSYSTEM OF GROUND REPRODUCER

the light levels greatly and this "masked" the effect sufficiently so that it was unnoticed).

Some work is still required to conduct further film tests to establish developing techniques. In addition, some effort is being spent to establish a satisfactory method of securing the 11" x 22" film to the drum. Final testing will include remaking pictures that were recorded on tape during the High Resolution Facsimile feasibility program.

4.8 PORTING MECHANISM

The second phase porting test has been completed. This test was conducted utilizing a redesigned cutter, a seal structure, and high strength bolts. (See previous bimonthly report). The test proceeded in accordance with the test plan and no difficulties were observed. Immediately following initiation, two simultaneous events occurred. First, the sphere commenced to rise into the air. Prior to reaching its maximum height of 10.5 inches, the balsa segments and skin in line with the projected centerline (or axis of travel) of the cutter moved out from the remainder of the limiter. The sphere then continued to rise and finally came to rest on the nine inch flat. Figure 20 shows the complete sphere immediately after the firing, while Figures 21 and 22 are of the gun/lower sphere assembly and the upper sphere (showing point of entry of the cutter) respectively. As can be seen in Figure 21, the inner barrel was physically disengaged from the threaded section of the thrust ring. The explosive force had also stripped the threads of several (6) nuts on the high strength bolts and allowed the outer barrel to separate from the thrust ring.

The cutter was observed to have canted 25 degrees during the firing sequence. Three possible explanations exist for this, and very probably all contributed to the act. Initially, the bolt and nuts disengaged by virtue of stripping the threads and allowing the outer valve to turn due to the explosive force. This turning action likewise turned the slip fit cutter initially. The second probable cause was the inner barrel hitting the rear of the cutter after the cutter has separated from the barrel. An abrasive or impact point was observed on the base of the cutter which coincides with a mark on the upper lip of the inner barrel.

A further possible cause of cutter deflection was observed upon removing the cutter from its lodged position in the impact limiter.

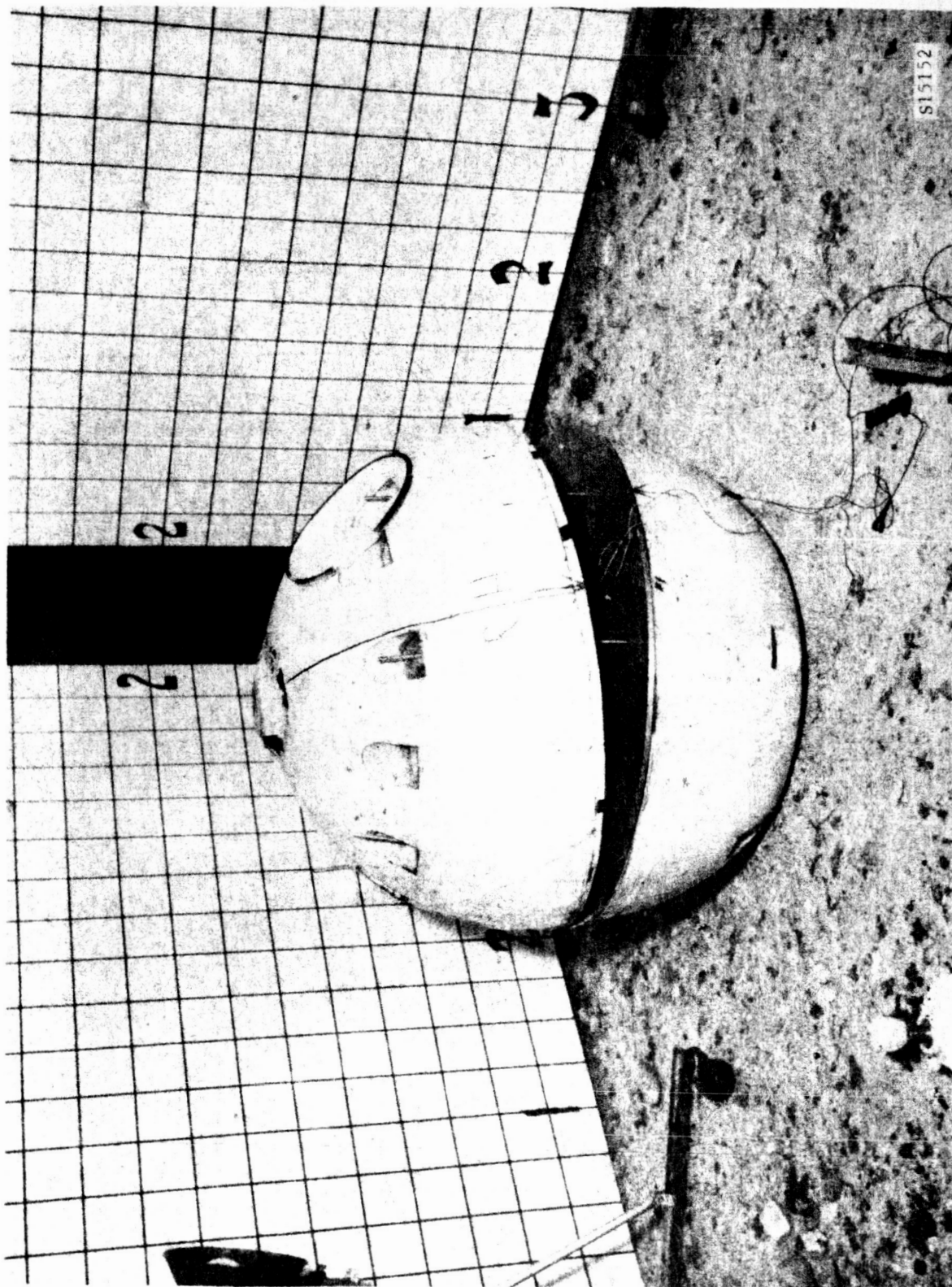


FIGURE 20. SECOND PHASE PORTING TEST: SPHERE SHOWN IMMEDIATELY AFTER FIRING

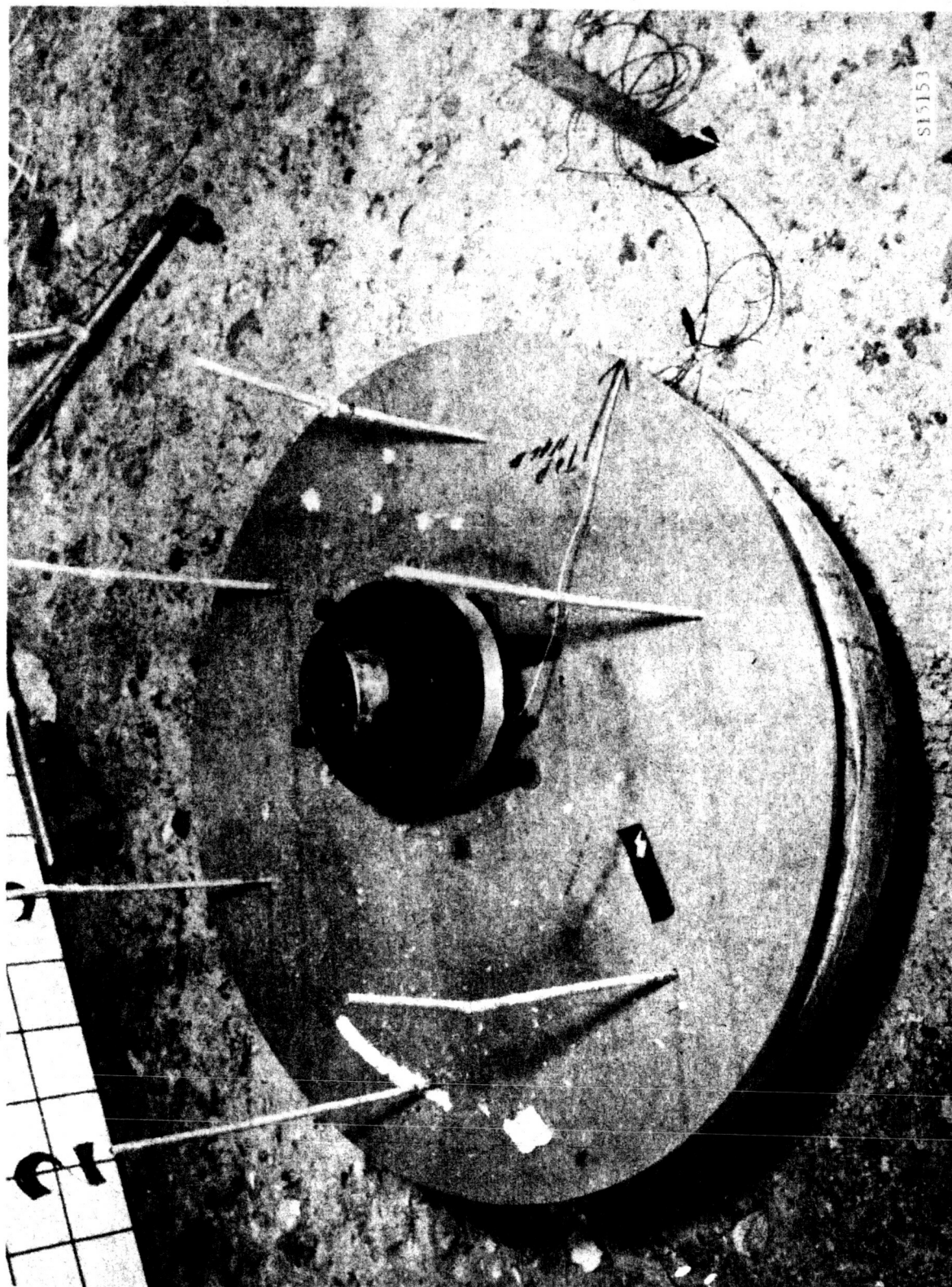


FIGURE 21. SECOND PHASE PORTING TEST: GUN/LOWER HEMISPHERE ASSEMBLY AFTER FIRING



FIGURE 22. SECOND PHASE PORTING TEST: UPPER HEMISPHERE AFTER FIRING

Several thicknesses of the flotation fluid shell material (figerglass) were curled around the outer diameter of the cutter and were still attached to the flotation shell rather than cut through as observed around the remainder of the cutter edge. These attached fibers were on the pivotal side of the cutter. It appears feasible that a flotation shell with localized hard or fibrous spots could cause the cutter to deflect.

The conclusions reached as a result of the first and second phase tests are as listed below:

- (1) A high velocity projectile which decelerates while penetrating fiberglass and balsa wood imparts upward lift to the sphere (this lift has previously been referred to as bounce).
- (2) Payload lift is undesirable in a system such as LFC. (It is assumed that some small but undefined amount of lift can be tolerated but this limit is at least an order of magnitude less than that experienced in the two porting tests conducted.)
- (3) An alternate method of porting utilizing a low impulse device on a sphere which is externally stabilized on the lunar terrain should be devised as a preferable replacement. A proposal to accomplish this end is now in preparation for submittal to JPL.

4.9 TRANSMITTER

The transmitter effort during this reporting period was primarily concerned with completion of drawings and fabrication of the mechanical parts for the two prototype test models. As of this date, all mechanical drawings with the exception of the overall chassis or housing drawing have been completed. The housing drawing is about 95 percent complete. Two housings and associated small parts have been fabricated and plated (See Figure 23). Electronic fabrication has started on the coil winding and component mounting board assembly.

A design review has been held on the LFC transmitter. As a result of this review, an analysis of anticipated deflection to the

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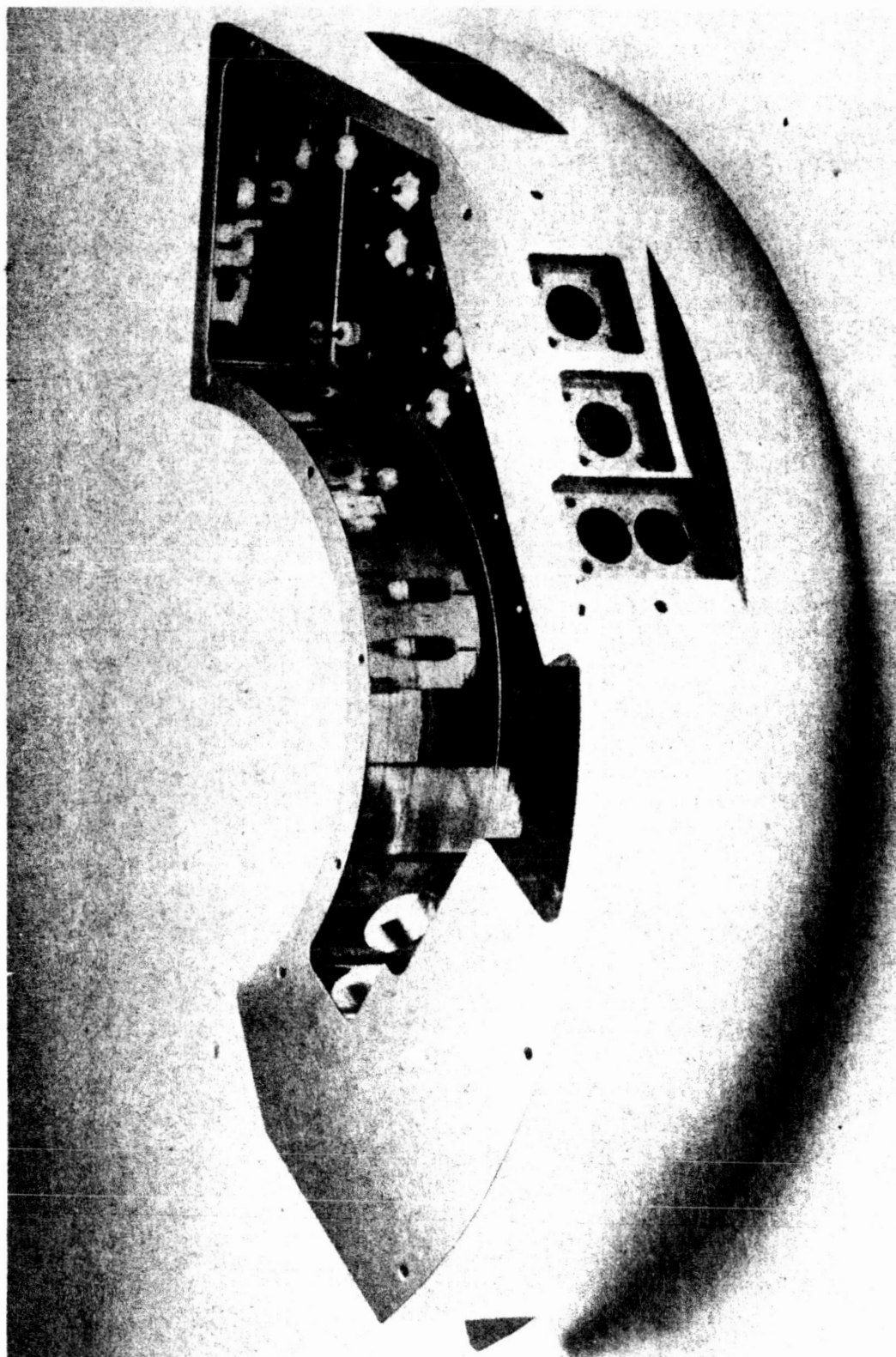


FIGURE 23. PROTOTYPE TRANSMITTER HOUSING

transmitter housing during impact has been prepared. The result of this effort predicts a maximum deflection of 0.024 inch of the battery cover plate into the d-c section of the transmitter. This deflection is not sufficient to short any wiring or components and will not cause detuning because of location of all r-f components on the opposite side of the center web. A deflection of 0.0012 inch of the side walls is also predicted. No problems are anticipated with this deflection as there is adequate lead length on interwired components to absorb the deflection.

Some concern has been expressed about the danger of arcing in the higher power stages during porting when critical pressure is reached. Vacuum chamber tests are being scheduled to determine the magnitude of this problem. If this does present a problem, critical component placement may be changed or the transmitter turn-on delayed until the porting pressure has been reduced.

A push-push 80 to 160 MC frequency doubler has been assembled on a breadboard as a possible replacement for the parallel 2N708 doubler now used. The present doubler provides marginal 160 MC drive for the TA2267 1-watt stage which requires forward biasing to provide sufficient gain over the entire temperature range. Increasing the drive to the 1-watt stage would reduce the amount of forward bias which in turn would raise the efficiency by operating more nearly Class C.

The push-push 2N708 circuit has provided an additional 1.6 db gain raising the 160 MC drive from 160 to 235 mw. Substituting Fairchild 2N2369's for the 2N708's increased for the power output to 390 mw which is sufficient to operate the 1-watt stage fully Class C with no forward bias. Further investigation is planned for the 2N2369's and shock qualification will be considered. It is anticipated that overall transmitter efficiency could be increased to 15 percent by use of the 2N2369 in a push-push doubler configuration. Comparative 80 to 160 MC doubler circuit data is shown in Figure 24.

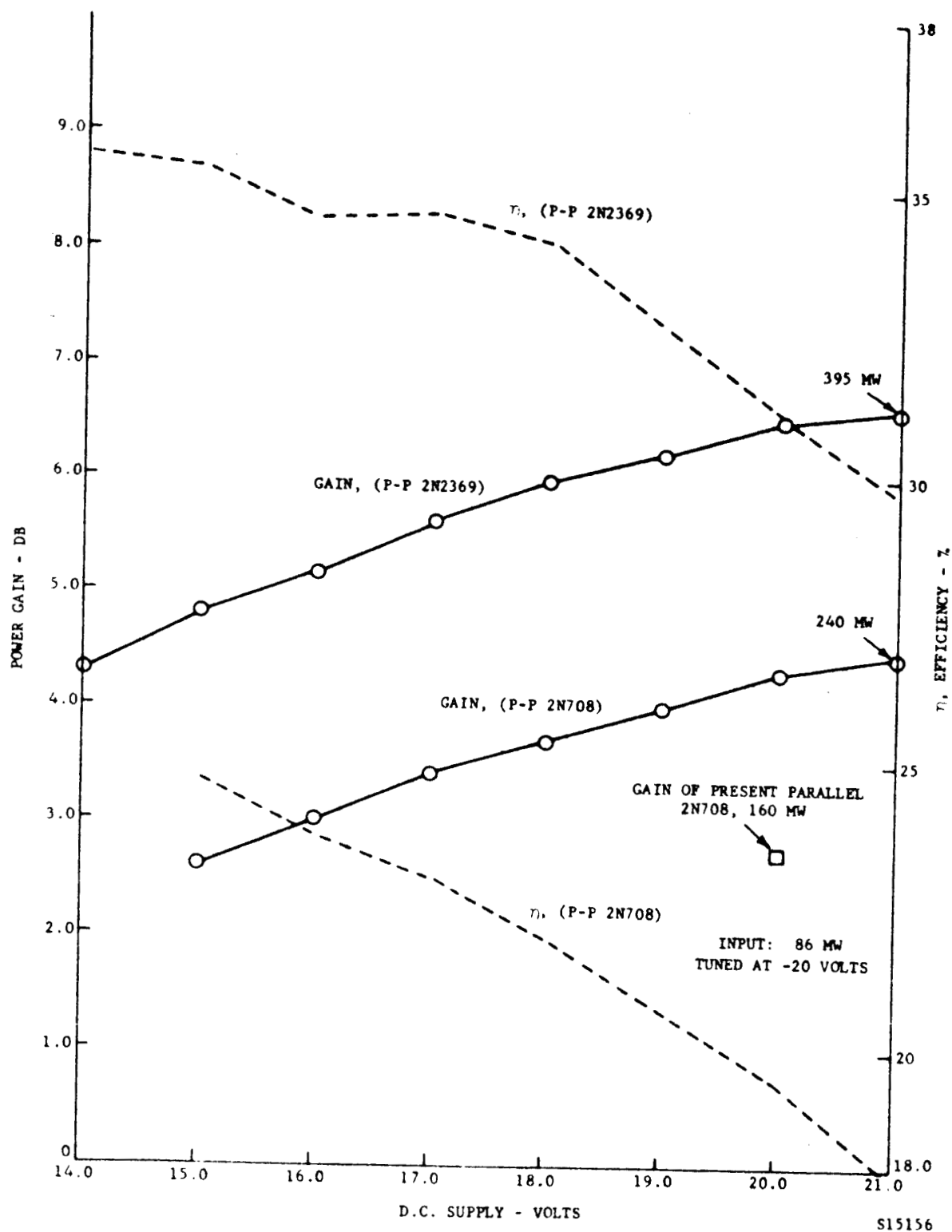


FIGURE 24. PUSH-PUSH FREQUENCY DOUBLER CHARACTERISTICS (80 to 160 MEGACYCLES)

SECTION 5

QUALITY ASSURANCE

5.1 RELIABILITY

Final Design Reviews have been performed on the azimuth drive assembly, extension mechanism, top tube assembly, and the structure; and an initial review conducted on the LFC transmitter. No major redesigns were considered necessary, however, several modifications were incorporated to improve performance, reliability, or producability of the assemblies.

Tests were performed on components of the LFC gear box to determine the amount of axial force required to cause slippage of the spur gears on the shaft. The test revealed that force in excess of 20 pounds was required before slippage occurred. This indicates that a considerable safety margin exists and no gear slippage should be anticipated since the expected force in the gears under a 3000 g impact is approximately one pound.

A test is in progress to determine the effect LFC flotation fluid would have on the physical properties of the selected "O" Ring materials: Buna-N, Viton-A and Neoprene. No deleterious effects on the materials have been observed or measured after momentary exposure to the fluid. After three weeks of immersion, a slight increase in the cross sectional diameter of all specimens was measured. Since the "O" Rings are being used only as static seals, this slight swelling will not be detrimental.

An investigation was conducted to determine the compatibility of a dry lubricant, molybdenum disulfide, with LFC materials. This

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investigation revealed that MoS_2 will accelerate corrosion of certain metals such as cadmium in the presence of high humidity; however, it will not have detrimental effects in the LFC application.

Effort is continuing by the components standards section in the selection and review of component and electronic parts, and in the updating of the Preferred Parts List. Of 148 part applications reviewed, 99 parts have been on the LFC or JPL preferred parts lists, and 8 have been approved through favorable qualification history on either other space projects or LFC component testing. Thirty-one items are still under investigation.

In lieu of an extensive list of preferred semiconductor devices directly related to LFC environments and reliability requirements, semiconductor selection is currently being guided by the LFC and JPL preferred parts lists, and by MIL-STD-701C.

5.2 QUALITY CONTROL

A review of all Nonconforming Material Reports written thus far during Phase I has been made to assure that proper engineering disposition is being accomplished on all discrepant items.

A review of vendors, being utilized during Phase I, was made to assure that all vendors are on the Quality Control Approved Vendor list.

A conference has been held with JPL personnel for the purpose of discussing the need for a Material Review Board during Phase I. It was agreed that a Material Review Board during Phase I will not be required. The present system of Quality Control documenting all discrepancies and referring them to Engineering for disposition is mutually acceptable.